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This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. ~~The articles~~ are written primarily by members of the staff of ONR Far East, the Air Force Office of Scientific Research, and the Army Research Office, with certain reports also being contributed by visiting stateside scientists. Occasionally, a regional scientist will be invited to submit an article covering his own work, considered to be of special interest. This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large. It is available free of charge to approved members of the DOD scientific community. Send written request describing DOD affiliation to: Director, Office of Naval Research, Liaison Office Far East, APO San Francisco 96503-0007.

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Cover: Kabuki started in the early 17th century, nearly 400 years ago. In some families kabuki performance is a family heritage, going back 10 generations and more, and children begin to practice their art at age 5. All roles are played by men. Some female impersonators, such as Tamasaburo Bando, are national celebrities. In the Meiji period, when Western drama with its new realism came to Japan, elements of realism and intense character development were introduced into "shin kabuki." Traditionally Noh, with its sober elements of Buddhist liturgy and Shinto and its mystical Spirits, was the theater of the samurai and aristocracy. Kabuki, which emphasizes duty (giri) and human sympathy (ninjo), but cloaked in humor, quick and sensational costume changes, and the spectacular (aerial flights and fire-spitting dragons), was the theater of the masses. Photo courtesy of Earl Callen.

THE 14TH CONDENSED MATTER PHYSICS MEETING OF THE AUSTRALIAN INSTITUTE OF PHYSICS

Earl Callen

The annual solid state meeting of the Australian Institute of Physics, held each year in February (summertime) and usually at Wagga Wagga, is a fine opportunity to meet a majority of those active in condensed matter physics in Australia and many from New Zealand. Wagga Wagga is about a 6-hour drive from Sydney, less from Canberra, and 1 day from Melbourne. At Wagga there is adequate time for talks, loads of posters (147 this year), and time to talk physics around meal tables, beer kegs, and the swimming pool of this pleasant, isolated campus. This article describes some of the talks at this year's meeting to give a picture of the diversity and quality of solid state down under.

INTRODUCTION

The Charles Stuart University has been newly created from a small agricultural college near Wagga Wagga, New South Wales, Australia. For 14 years Australian solid state physicists have gathered each summer for the Wagga meeting (usually and from now on in February and usually here, but in New Zealand in 1992). This year 180 scientists registered to attend the 2.5 day meeting. At Wagga no sessions are in parallel. Conferees eat together and relax together at wine-tasting and Trivial Pursuits. Except for the uncrowded open-air swimming pool (the temperature sometimes sticks at 40 °C), there are few distractions to divert conferees from each other. One can meet and talk at leisure with most of the solid state physicists of Australia (fewer from far-away Perth) and many of those from New Zealand. This article describes some of this year's talks.

PHYSICAL PROPERTIES OF SEA ICE

H.J. Trodahl of Victoria University, Wellington, New Zealand, has been studying the optical properties of sea ice at McMurdo Sound, Antarctica (Ref 1). To be meaningful the studies must be made *in situ* because the physical properties of the ice change within minutes when it is lifted. Sea ice is at the very cold air temperature at the top and at the freezing point of seawater (-2 °C) at its lower surface. It may be 5 to 10 feet thick. Sea ice contains air bubbles, vertical columnar brine inclusions, and precipitated salts. The distribution of inclusions varies with depth and changes with the seasons. Inclusions have a major uniaxial effect on light scattering and absorption. This light is necessary for life forms on the bottom surface of the ice, the beginning of the aquatic food chain.

INFRARED OPTICAL FIBERS

Gavan Rosman of Telecom Australia Research Laboratory, Clayton, spoke of the Telecom Monash efforts of the past decade to produce a better optical fiber. It is difficult to surpass silica-based glass. One wants a glass with low loss over a wide frequency range, but light loss is boxed in between two mechanism--scattering of light at short wavelengths and multiphonon absorption on the long wavelength side. To broaden the window, researchers look for materials with a lower temperature of glass formation and with heavier elements less stiffly bonded. Compared to silica the resulting glasses suffer in mechanical properties. Nonoxide glasses are candidates. Telecom has worked extensively on heavy metal-fluoride fibers.

LIQUIDS--PERSPECTIVES, ADVANCES, AND FRONTIERS

I.K. Snook, Royal Melbourne Institute of Technology (Ref 2). By experimental studies, particularly scattering experiments, by large-scale computer simulation, and by analytic methods such as hard sphere perturbation methods, the static and dynamic structure of liquids are now measured with high precision and are increasingly understood. Theory and numerical calculations agree with experimental findings on equations of state and on transport properties of liquids and mixtures such as liquid inert gases, ionic melts, liquid metals, and liquid water. Fluids at interfaces, complex fluids, suspensions of particles in fluids, and melting at interfaces are among areas of current research.

THE STRUCTURE OF LIQUID SURFACES AND WETTING PHENOMENA

David Beagelhole, Victoria University, Wellington, New Zealand. On a melting solid in equilibrium with its vapor there is a liquid surface layer. How the liquid density varies through this transition region or even how thick this layer is are not easy issues to resolve experimentally. For thicknesses small compared to the wavelength of light (not the case in the interesting critical region), ellipsometry measures the spatial integral of [(dielectric constant of the liquid minus that of the solid) times (dielectric constant of the liquid minus that of the vapor)]. Characterized by surface layer thickness, liquids appear to fall systematically into certain definite empirical groups. Measurements have also been made on CCl_4 at the critical temperature, where the density of the liquid equals the density of the vapor. In wetting, a thin layer of a liquid spreads over another liquid or solid. By ellipsometry the microscopic thickness of such layers, the spread of drops, and capillary phenomena can be studied. Water wetting layers appear to be present on ice below 0 °C--the surface melts first. Inert impurities have a large effect on surface melting and on the (temperature dependent) thickness of the premelting layer.

EXPERIMENTAL VERIFICATION OF THE AHARONOV-CASHER EFFECT FOR NEUTRONS WITH A CRYSTAL INTERFEROMETER

Goeffrey I. Opat, School of Physics, University of Melbourne. The Aharonov-Bohm effect, a startling confirmation of the fundamental role in quantum physics of

potentials (through the Hamiltonian), rather than forces, is as follows: a coherent beam of charged particles (for example, the wave function of a propagating electron) is divided into two beams that pass through different electrical potentials (one beam passes through a Faraday cage), or electromagnetic vector potentials (a solenoid with an enclosed magnetic field between the two beams), but not through electric or magnetic fields. The split beams are then recombined. A diffraction pattern is observed, depending upon a phase difference introduced into the wave functions over the split-beam portion. The phase of each beam has been shifted proportional to the integral over time of the electrical potential or the integral around the path of the vector potential. The Aharonov-Bohm effect, and a beautiful confirmation of it by A. Tonomura, is described in a *Scientific Bulletin* article (Ref 3). The analogous Aharonov-Casher (A-C) effect has now been confirmed by Alberto Cimmino, Goeffrey Opat, and Anthony Klein of the University of Melbourne and Helmut Kaiser, Samuel Werner, Muhammad Arif, and Russell Clothier of the University of Missouri at Columbia (Ref 4). The wave function of neutrons is shifted in travelling around electrical charge. In the magnetic form of the Aharonov-Bohm effect the magnetic field in the solenoid can be thought of as being replaced by an infinite line of aligned magnetic dipoles. In the A-C effect the charge and dipoles are interchanged; a magnetic dipole with its spin parallel to a line of charge is diffracted around the line of charge. The effect is transformed to the phase shift of a particle with a magnetic dipole moment in an electric field. In a sense the effect is less dramatic than the original A-B effect, since the dipole, the neutron, must sense the electric field, not merely the potential, of the line of charge. But in the special case originally proposed by Aharonov and Casher (Ref 5) there is no force on the dipole, even though there is a magnetic field seen by the neutral particle moving in an electric field. The torque on the dipole goes as μxB, and this is zero when the dipole is parallel to the line of charge. In the lovely and ingenious experiment, *unpolarized* thermal neutrons are diffracted by a perfect silicon single crystal neutron interferometer. The line of charge is replaced by a metal cylindrical electrode charged to 45 kV. Since some fixed, mechanical path difference between the two legs of the crystal interferometer is experimentally inevitable, this is compensated for by tipping the interferometer around a horizontal axis to introduce a slight and adjustable difference in gravitational potential. The sum of the experimental offset phase shift and gravitational phase shift is adjusted to zero (mod 2π). A particularly ingenious innovation is the introduction of a magnetic field parallel to the line of charge. Spin precession of the dipole in the magnetic field introduces a spin-dependent phase shift which is set at $\pi/2$. At this value (or any odd multiple) sensitivity to the A-C phase shift is greatest because it is then linear in the electric field strength. Several months counting are required to collect enough neutrons to lower statistical uncertainty. At the time of the Wagga report the ratio of experimental phase shift to that predicted theoretically was 1.3 ± 0.4.

PULLING STRINGS IN SUPERFLUID HELIUM-3

Tony Guenault, Lancaster University, United Kingdom. At 0 K the entropy is zero. Liquids are disordered. Helium-3 remains a liquid to 0 K. How is the paradox resolved? Helium-3 is a Fermi liquid. At about 1 mK

it starts to transform to a paired superfluid state. By 0.1 mK most of the fluid is condensed in the paired ground state and the fraction of normal fluid is low. The normal fluid then constitutes excitations, quasiparticles, whose mean free path is long because of their low density. These ballistic quasiparticles then collide with the containing vessel. Vibrating wires can be used as thermometers, heaters, quasiparticle generators, and quasiparticle detectors. Properties of the elementary excitations, including their intrinsically nonlinear damping, are being elucidated by vibrating wire experiments.

HYSTERETIC LOSSES IN HIGH T_c SUPERCONDUCTORS

Karl-Heinz Müller, CSIRO Division of Applied Physics, Lindfield, New South Wales (Ref 6). In applications such as ac power transmission, ac loss in the superconducting state is an important material engineering parameter. So far, unfavorably high ac losses have been found in ceramic bulk high T_c superconductors. In ordinary type II superconductors low frequency hysteresis loss is the result of irreversible dissipation accompanying motion of vortices of magnetic flux due to the Lorentz force. This does not appear to be the origin of the high losses in the ceramics. Müller and coworkers show that at low magnetic fields the high losses in polycrystalline YBCO are mainly pinning losses originating from Josephson vortices moving *between* grains, while at high fields the losses are due to moving Abrikosov vortices *inside* the grains. The minimum in the ac loss versus dc field strength curve is found to be due to the weak field dependence of the intergranular pinning force density, not to surface barriers to flux entry or exit as in conventional superconductors.

THE UNIVERSAL ABSENCE OF MACROSCOPIC LORENTZ FORCE CONTRIBUTIONS TO HIGH T_c SUPERCONDUCTOR ENERGY DISSIPATION

G.B. Smith, Department of Applied Physics, University of Technology, Sydney (Ref 7). Smith, with groups at the University of Technology and at CSIRO, Lindfield, has performed experiments that complement the investigations of loss mechanisms in high T_c superconductors described in the previous abstract. In conventional superconductors the principal dissipation mechanism is flux jumps between pinning centers. The high T_c ceramics are different. Lorentz forces, at least on a macroscopic scale, appear to play no part in dissipation. Loss curves in high T_c superconductors are independent of the direction of current relative to ambient magnetic field (after correcting for demagnetization). If loss depended upon the Lorentz force **JxB**, it is implausible that it would be the same with $\mathbf{J} \perp \mathbf{B}$ as with $\mathbf{J} \parallel \mathbf{B}$; in the latter case there should be no loss. Experiments have been performed upon highly oriented thin films, randomly oriented bulk samples, with current densities ranging over more than two orders of magnitude, in fields from 0.01 to 7 tesla, and at temperatures ranging down to below the irreversible temperature, at which the flux creep mechanism is operative in conventional superconductors. Loss results from some activation process, and the activation energies depend upon the magnitudes of both the current and the magnetic field, but not upon their relative direction. Localized fluctuations at Josephson junctions seem to be implicated.

SCANNING TUNNELING MICROSCOPY OF POLYMERS

J.W. White, Research School of Chemistry, Australian National University, Canberra. Scanning tunneling microscopy is performed only with difficulty on weakly conducting substances. This talk constitutes the first report of imaging by scanning tunneling microscopy of a polymer made conducting by dissolving an amphophilic substance. Polyacetylene can be made soluble in organic solvents by copolymerizing with a soluble species such as polyisoprene. Scanning tunneling microscopy reveals that the copolymer molecules thus formed aggregate in the same way as soap bubbles but form lamellar structures. A reasonable explanation is that aggregation happens because the molecules are amphophilic (can have either positive or negative valence). Conductivity increases markedly at about 20 percent polyacetylene component, presumably a percolation threshold.

METASTABLE PHASES OF METALS AND ALLOYS

Earl Callen, Office of Naval Research Far East (Ref 8). Equilibrium phase diagrams can be used to advantage to predict and understand metastable behavior. As one example (of many surveyed in this review talk) consider two substances whose phase diagram would have had a eutectic but for the existence of an intermetallic compound. Intermetallic compounds, despite low Gibbs free energy, can often be suppressed because they are ordered and exist only in a narrow composition range. Suppose one then mechanically alloys at a temperature (room temperature) too low for atomic diffusion powders of the two components in the ratio of the intermetallic compound. By continued ball milling beyond the superplastic domain the mixture can be made so complete, within each particle, that the atoms are within a diffusion length of their ordered location, but the mixture remains disordered. A somewhat inhomogeneous alloy is formed, can be compacted, and is stable. Its Gibbs free energy is not far from that of a linear combination (at that composition) of the free energies of the two terminal components. Since the composition is within the range that would have been a liquid on the equilibrium diagram except for the existence of the intermetallic compound, and since room temperature is below the glass transition, continued mechanical alloying will often form an amorphous alloy. But the intermetallic has a lower free energy. So when the solid metal pellet is heated to a temperature at which diffusion and structural transformation can occur, a self-sustaining solid state reaction takes place, heat is evolved--sometimes enough to melt the pellet--and the ordered intermetallic compound forms.

NUCLEAR ORIENTATION STUDY OF THE QUASI-1D ANTIFERROMAGNET $CsMnCl_3 \cdot 2H_2O$

G.J. Bowden, School of Physics, University of New South Wales (NSW), Kensington (Ref 9). Bowden, with groups at NSW, Kensington, and at the Department of Physics, University College, Australian Defense Force Academy, Campbell, has been using the dilution refrigerator of the Australian Defense Force Academy to cool $CsMnCl_3 \cdot 2H_2O$ to less than 15 mK. The results support the picture of a very large (30 percent) spin reduction in this quasi-1D antiferromagnet. This is reinforced by a

random phase approximation calculation. (But of course the calculation is based upon the initial assumption of a Néel state. Though it is too far from self-consistent to provide a quantitatively reliable estimate of the spin reduction, the calculation does suggest that it is large.) Bowden also sees evidence of solitons. In the ferromagnet a soliton is a moving domain wall; the domain wall lowers magnetostatic energy. In the antiferromagnet the soliton is a propagating boundary of an antiphase domain. There is no magnetostatic driving force for antiphase domains, only the luck of the draw at nucleation. But solitons should be present in thermodynamic equilibrium, and should propagate, as to do so requires no energy in the perfect crystal. In the antiferromagnet they are not suppressed or otherwise much affected by a magnetic field, even a spin flop field. This is observed.

REFERENCES

1. H.J. Trodahl and R.G. Buckley, *Science* 245, 194 (1989); *Cold Regions Science and Technology* 16, 305 (1989); *ibid.* 14, 201 (1987); *Nature* 326, 867 (1987).

2. M.P. Allen and D.J. Tildesly, *Computer Simulation of Liquids* (Oxford University Press, 1989); W. van Meg n and I.K. Snook, *Molecular Physics* 54, 741 (1985); *idem.*, *Advances in Colloid and Interface Science* 21, 119-194 (1984); J.W.M. Frenken and I.F. van der Veen, *Phys. Rev. Lett.* 54, 134 (1985).

3. A. Tonomura and E. Callen, *Scientific Bulletin* 12(3), 93 (July/September 1987).

4. A. Cimmino, G.I. Opat, A.G. Klein, H. Kaiser, S.A. Werner, M. Arif, and R. Clothier, *Phys. Rev. Lett.* 63, 380 (1989).

5. Y. Aharonov and A. Casher, *Phys. Rev. Lett.* 53, 319 (1984); *Physics Today* 43(1), 17 (January 1990).

6. K.-H. Müller, J.C. Macfarlane, and R. Driver, *Physica* C158, 69, 366 (1989); K.-H. Müller and A.J. Pauza, *Physica C* (in print); K.-H. Müller, *Physica* C159, 717 (1989).

7. G.B. Smith, J.M. Bell, N. Savvides, S. Filipczuk, and C. Andrikidis, *Aust. J. Physics* 40, 431 (1989); S. Kambe, M. Naito, K. Kitazawa, I. Tanaka, and H. Kojima, *Physica* C 60, 243 (1989); K.C. Woo, K.E. Gray, R.T. Kampworth, H.J. Kang, S.J. Stein, R. East, and D.M. McKay, *Phys. Rev. Lett.* 63, 1877 (1989).

8. E. Callen, F. Pettit, and P. Shingu, *Scientific Information Bulletin* 14(2), 1 (April/June 1989).

9. G.J. Bowden and J.P.D. Martin, *J. Phys. Condens. Matter* 1, 179 (1989); J.P.D. Martin, Ph.D. thesis, University of New South Wales (1988).

Earl Callen is a member of the staff of the Office of Naval Research Far East. He is a Professor Emeritus of The American University. He has been active in the physics of magnetoelastic phenomena and amorphous magnetism.

10TH AUSTRALASIAN FLUID MECHANICS CONFERENCE

Hideo Yoshihara

Selected papers presented at the 10th Australasian Fluid Mechanics Conference at the University of Melbourne are reviewed. Following this discussion, conversations with Professors Graeme Bird (direct simulation Monte Carlo method) and Clive Fletcher (computational fluid dynamics and supercomputers), both of the University of Sydney, are described.

10TH AUSTRALASIAN FLUID MECHANICS CONFERENCE

This conference, which was held from 11 to 15 December 1989 at the University of Melbourne, emphasized fundamental fluid dynamics much like the American Physical Society fluid dynamics meetings. The emphasis of this meeting was computational and experimental turbulence. This series of meetings, held every 3 years, originally covered more empirical engineering topics such as hydraulics and was primarily a national meeting with New Zealand. During the last few conferences emphasis was shifted to more fundamental aspects of fluid dynamics and the meeting was expanded to include international participation. The conference was chaired by Professor Anthony Perry of the Mechanical Engineering Department, University of Melbourne, and honored Professor P. Joubert of the University of Melbourne, a pioneer of Australian fluid dynamics, upon his retirement. Total attendance was 229 with the breakdown as follows: Australia, 154; United States, 34; Germany, 11; United Kingdom, 7; Japan, 5; New Zealand, 5; and India, Singapore, Canada, Switzerland, and Israel, 13.

Presentations included 10 invited talks of 60 minutes duration given at the beginning of the morning and afternoon sessions each day. The contributed talks were of 20 minutes duration presented in four concurrent sessions with six papers per day in each session. The highlight of the conference was the 10 invited talks by outstanding fluid dynamicists. These included George Batchelor (Cambridge U.), William Reynolds (Stanford U.), Hans Hornung (Cal Tech), John Lumley (Cornell U.), Anthony Leonard (Cal Tech), Roddam Narasimha (National Aeronautical Lab (NAL)-Bangalore), Brian Cantwell (Stanford U.), Morton Denn (U. of Calif.-Berkeley), Ray Stalker (U. of Queensland), and J.F. Clarke (Cranfield Inst. of Tech.).

Invited Papers*

George Batchelor (Cambridge U.), "The Dynamics of a Mixture of Two Components": Professor George Batchelor is an

* It was fortunate for this report that all of the written versions of the invited talks were in the *Proceedings*, and this infrequent accomplishment is to be credited to Professor Tony Perry and Dr. M. Chong, who edited the *Proceedings*.

internationally recognized researcher of fundamental turbulence and is an alumnus of Melbourne University. He reviewed the dynamics of fluids containing macroscopic particles by dividing the flows into three classes. The first is the well-developed case where there is no-slip between the gas and the particles. More difficult and less established are the cases with slip. He first reviewed the special case of the dusty gas where there are a number of results available. The final and not-yet satisfactorily formulated case was the slip-case with fluid dynamic interaction between the particulates. Difficulty arises here since the particulate velocities must be treated statistically. Use of examples made clearer the physics of these flows and their theoretical difficulties and limitations.

William Reynolds (Stanford U.), "Effects of Rotation on Homogeneous Turbulence": Professor Reynolds is a longtime expert on fundamental turbulence and is a key member of the NASA-Ames/Stanford Center for Turbulence Research. The present paper was motivated by a direct simulation calculation showing that non-isotropy of turbulence was reduced by rotation. He used the rapid distortion theory for homogeneous turbulence to evolve the mechanism for this significant effect of rotation. These results are the stepping stones to turbulence models applicable in vortices to enable prediction of bursting.

Hans Hornung (Cal Tech), "Vorticity Generation and Transport": Professor Hans Hornung is also an alumnus of Melbourne University and is presently the director of the Graduate Aeronautical Laboratory (GAL), replacing Hans Liepmann. His paper assumes the solution to be known at the no-slip wall, and from this he constructs the topology of the vorticity lines for planar Newtonian flows. Construction of the streamlines and vorticity lines, given the Navier/Stokes solution, has been the subject of other interesting contributions by University of Melbourne researchers Tony Perry (chairman of the conference) and Dr. Chong and was also the subject of several other papers at the conference.

John Lumley (Cornell U.), "Low Dimensional Models of the Wall Region of a Turbulent Boundary Layer, and the Possibility of Control": Coherent features of the wall region of the boundary layer such as bursts (generators of turbulence) are modeled by low-order eigenfunctions generated by periodic boundary conditions in the homogeneous directions. This low wave number modeling then was used to suggest means to reduce turbulence, for example, using polymer additives.

Anthony Leonard (Cal Tech), "New Approaches to Problems in Fluid Mechanical Mixing": Knowing a chaotic or turbulent solution, there is then the task of interpreting the mass of data, for example, by tracking particles (transport modeling) or interfaces (for reacting flows.) In this presentation a first step is taken considering a time-periodic planar case of a vortex pair in an external oscillating strain-rate field. The results are analyzed by studying lobe-like structures relative to invariant curves in the Poincare velocity map. There is interest in extensions of this technique to the three-dimensional case; investigations are planned for the future.

Roddam Narasimha (NAL-Bangalore), "Building Bridges Between Dynamic Chaos and Open-Flow Turbulence": A dynamic system defined by a set of three nonlinear, first order ordinary differential equations was evolved, producing chaos

with many key features of open-flow turbulence such as the proper cascading of "turbulent energy." Previous systems did not possess these important features. Professor Narasimha expressed optimism in the relevance of dynamic system chaos to open-flow turbulence.

Brian Cantwell, G. Lewis, and J. Chen (Stanford U.), "Topology of Three-Dimensional Variable Density Flows": Procedures to interpret unsteady compressible flow fields obtained either experimentally or computationally are presented that follow earlier approaches by the Melbourne University researchers. Specifically, the topology of the flow is obtained by analyzing singular points. Examples of the unsteady diffusion flame and a wake were given. The recommended quantity to track was the Galilean-invariant pressure gradient. Efforts such as this are essential to interpret complex turbulent flow fields for evolving improved turbulence models.

Morton Denn (U. of Calif.-Berkeley), "Mechanics of Anisotropic Fluids": The fluid dynamics of an anisotropic liquid flow, where the anisotropy is caused by suspensions of high-aspect ratio particles or by rigid high-aspect ratio molecules, is reviewed. These effects are important for the performance of fiber-reinforced composite materials or in advanced optical devices.

J.F. Clarke (Cranfield Inst. of Tech.), "Developments in Detonation Theory": The evolution of detonation waves is studied using analytical and computational methods. It was found that the unsteady induction region plays an important role in the subsequent detonation process.

Ray Stalker (U. of Queensland), "Dissociating Flows in Hypervelocity Aerodynamics": Simple pre-design level tools for computing detached shock flows over blunt noses were suggested, assuming direct dissociation without recombination. Stalker's results, however, are not applicable in practical cases where the flow is not inviscid and heat transfer is significant.

Professor Stalker, before and after his keynote talk, passed out brochures on his private company, WBM-STALKER, which designs and fabricates hypervelocity shock tunnels for testing aerospaceplane-type configurations and scramjet engines. It presently has three contracts in the United States with the Rockwell Rocketdyne Company, General Applied Science Laboratory (Long Island), and the California Institute of Technology. Professor Stalker is highly experienced in this area, having operated high temperature shock tunnels at the University of Queensland for many years. He was invited by the AGARD Fluid Dynamics Panel in 1987 to present an invited paper on his hypersonic test experiences. Most impressive was the Rocketdyne shock tunnel, which is piston-driven with an expansion tube following the shock tube. The brochure gave the overall length as over 100 meters with a weight of more than 700 tons. This facility is sized to enable testing, for example, of a full-scale scramjet engine. The Cal Tech shock tunnel is smaller, about 50 meters long, and it will be installed on the roof of the GAL building. The Mach number and total temperature of these facilities were not given, but it was stated that testing can be carried out for near-orbital speeds. It was mentioned by Professor Hornung that support for the Cal Tech facility was furnished in part by Rockwell.

Contributed Papers

In general, the quality of these papers was high, comparing favorably in many cases with the quality of some of the invited talks. The subjects covered and the number of

papers on each subject are as follows: turbulent flow including transition (30), compressible flow (15), acoustics (12), stratified flows (9), computational fluid dynamics (CFD) (9), geophysics (9), experimental techniques (9), multi-phase flows (6), environmental fluid dynamics (6), and wind engineering (6). Other sessions included reacting flows and heat transfer/convection. A discussion of the presentations attended follows.

D. Driver and J. Johnson (Stanford U.), "Three-Dimensional Boundary Layer Flow with Streamwise Adverse Pressure Gradient": Laser velocimeter measurements of the Reynolds stresses were made for boundary layers with large crossflow. Reduction of the streamwise Reynolds stress by the crossflow was quantitatively determined, and this effect will be particularly important in the shock/boundary layer interaction for transonic swept wings.

J. Flores (NASA-Ames), "The Simulation of Hypersonic Flow Using a Zonal Approach"; D. Chaussee (NASA-Ames), "Hypersonic 3-D Flow Past Winged Bodies"; N. Chaderjian and J. Flores (NASA-Ames), "Transonic Viscous Flow Computations About a Complete Aircraft Using the Navier/Stokes Equations": These three papers, as well as that of Dr. T. Edwards below, demonstrate the significant progress in the calculation of complex configurations using Navier/Stokes methods. Computing costs must be significantly reduced before such procedures can become viable design tools. Unfortunately, the authors were unable to present their papers which were, however, ably presented by Dr. Edwards.

A. Hilgenstock, H. Vollmers, and U. Dallmann (DLR-Gottingen), "Open Separation and Vortex Formation-Numerical Simulation and Analysis of a Delta Wing Flow": Further building blocks for the understanding of the puzzle of vortex bursting were given.

T. Lim, T. Nickels, and M. Chong (U. of Melbourne), "A Note on the Cause of Rebound in Vortex Ring/Wall Interactions": Water tank tests were skillfully carried out, determining the wall boundary layer to be the cause for the rebound.

K. Gersten (U. of Bochum, West Germany), "Some Open Questions in Turbulence Modeling from Viewpoint of Asymptotic Theory": Large Reynolds number limit was used to weed out inconsistent algebraic turbulence models.

T. Edwards (NASA-Ames), "Numerical Investigation of Hypersonic Exhaust Plume/Afterbody Flow Fields": Timely and important propulsion/airframe interactions were calculated with the Navier/Stokes code.

VISIT TO THE UNIVERSITY OF SYDNEY

Professor Graeme Bird (Aeronautical Engineering Department)

Graeme Bird, by consensus, is the "premier expert" on the direct simulation Monte Carlo (DSMC) method. I last talked with Professor Bird around 1960 in San Diego, and he has been working on DSMC since then. He will retire in February 1990 from the University of Sydney but will continue DSMC research in his own company, which operates out of a small room in the basement of his home, where we met during my visit to Sydney. He has been supported by NASA-Langley during the past 5 years, received an American Institute for Aeronautics and Astronautics (AIAA) Award in 1989 for his DSMC research, and was recently elected Fellow of the AIAA.

In the outer fringes of the earth's atmosphere (80 to 100 km), the flow about a space vehicle cannot be treated as a continuum but must be treated by a method that takes into account the molecular makeup of the air. The DSMC method is just such a method; it traces the trajectories, not of individual molecules, but of representative particles made up of many molecules. The key is to model the representative particles to reflect the statistical average behavior of the molecules they contain. (Needless to say, there is some controversy as to the proper formulation of the representative particles.) Graeme Bird's DSMC method has yielded impressive results, for example, matching closely with Navier/Stokes results for weak normal shock profiles, which is a severe test case. This method has received wide support in the United States, in particular by NASA-Langley and aerospace companies such as Boeing and General Dynamics, who have purchased his production code. Though the method entails repeated independent calculations for each representative particle, extensive scalar preparatory processing in each determination renders large vector supercomputers ineffective. Accordingly, Professor Bird carried out his calculations on the U.S. space shuttle at 120 km from his basement office with a PC with 8 MB memory. An essential element in his production code is the adaptive cartesian mesh, which is used both for sampling the macroscopic properties as well as determining collision pairs to be used in his model. His current NASA grant calls for adapting his code to a large supercomputer, utilizing the faster speed and larger memory to carry out expeditiously more extensive calculations such as extending the altitude down to 100 km for the space shuttle. In the near future calculations can be expected down to Knudsen numbers overlapping Navier/Stokes solutions, and this would be a landmark accomplishment. (See References 1 and 2 for discussions relating to DSMC methods.*)

Professor Bird's calculations are impressive, but even more impressive will be the results that can be expected from him during his "retirement" years.

Dr. Clive Fletcher (Mechanical Engineering Department)

Dr. Fletcher holds the rank of Reader, which falls between Professor and Associate Professor. He is on many international CFD committees and is a leading CFD researcher in Australia. I visited Dr. Fletcher to obtain an overview of the supercomputer environment in Australia.

Fluid dynamics research at the Universities of Sydney and Melbourne is mostly of a fundamental nature, treating simple basic flows, so that onsite minicomputers largely serve their needs. There is, however, a need for supercomputers, for example, for turbulence research, and a Cray XMP (probably a low end model) is available at the Leading Edge Technology Company in Melbourne that can be accessed via telephone. This is a private firm that operates in close collaboration with Cray Research-Australia. Leading Edge Technology is also scheduled shortly to receive a YMP.

*1. G.A. Bird, "Perception of numerical methods in rarefied gasdynamics," in *Rarefied Gas Dynamics: Theoretical and Computational Techniques*, edited by E.P. Muntz, D.P. Weaver, and D.H. Campbell, Vol. 18 of *Progress in Astronautics and Aeronautics* (AIAA, Washington, DC, 1989).

2. G.S. Bird, "Direct simulation of gas flows at the molecular level," *Communications in Applied Numerical Methods* **4**, 165-172 (1988).

The primary supercomputer user in Australia is the nuclear industry, as is the case in many countries. A Fujitsu VP-100 (267 MFLOP) is installed at the Australian Nuclear Science and Technology Laboratory. This organization has sponsored international supercomputer conferences; the second of the series was held at Wollongong University (just south of Sydney) during 12-14 December 1989, concurrent with the Australasian Fluid Dynamics Conference. Dr. Fletcher gave me a copy of the program. Keynote addresses were given by representatives of supercomputer firms: Blaskovich (Cray), "Supercomputers: One Third of the Environmental Formula"; Clementi (IBM), "Modern Techniques in Computational Chemistry"; Tahara (Fujitsu), "Trend of Supercomputer Usage in Japan"; and Tannenbaum (NNSX, U.S. representative of NEC), "Technological Advances in the Next Generation of Supercomputing." The Fujitsu speaker, N. Tahara, participated in the Office of Naval Research Navier/Stokes benchmark.

Hideo Yoshihara arrived in Tokyo in April 1988 for a 2-year assignment as a liaison scientist for the Office of Naval Research. His assignment is to follow the progress of advanced supercomputers and to review and assess the viscous flow simulation research in the Far East. Dr. Yoshihara formerly was with the Boeing Company, where he was Engineering Manager for Applied Computational Aerodynamics. He was also an affiliate professor in the Department of Aeronautics and Astronautics of the University of Washington, an AIAA Fellow, and a former member of the Fluid Dynamics Panel of AGARD/NATO.

JAPANESE ADVANCED TECHNOLOGY FOR NOVEL SHIP PROPULSION CONCEPTS

Justin H. McCarthy

Four ongoing Japanese development efforts on ship propulsors and powering are described. They deal with superconducting magnetohydrodynamic propulsion, propeller boss cap fins and contrarotating propellers to increase propulsive efficiency, and a newly established research and development program on super high-speed vessels.

INTRODUCTION

I returned to Japan in September 1989 to revisit a number of research institutions that I had visited 3 years earlier during a 14-month tour of duty with the Office of Naval Research Far East in Tokyo. Despite the lingering depression in Japanese as well as worldwide shipbuilding, Japan continues to allocate significant resources to ship research and development (R&D) with emphasis on far-term, moderate- and high-risk concepts. This article describes four novel technology developments related to ship propulsion which may be of general interest to readers of this publication. As in previous visits, I continue to be impressed by the competence, versatility, and vision of the Japanese professionals conducting these and other investigations.

The first investigation concerns R&D on magnetohydrodynamic propulsion and its demonstration on a 30 m vehicle designed for this purpose. This work is being led by the Japan Foundation for Shipbuilding Advancement under Ryoichi Sasakawa. The second and third investigations are concerned with increased propulsive efficiency achieved primarily by reduction of kinetic energy swirl losses downstream of conventional propellers. One concept, developed and extensively employed by Mitsui O.S.K. Lines, uses evenly spaced short-span fins on the bossing immediately aft of a propeller. The second concept, involving contrarotating propellers and advanced machinery developments, was recently demonstrated by Ishikawajima-Harima Heavy Industries Co., Ltd. on a bulk carrier. Finally, a new and ambitious 5-year Japanese national effort to create a super high-speed vessel, "Techno-Superliner '93," is described.

SUPERCONDUCTING MAGNETOHYDRODYNAMIC (MHD) SHIP PROPULSION

In June 1985 the Japan Foundation for Shipbuilding Advancement (JAFSA) formed a committee to lead a pioneering R&D effort on superconducting MHD propulsion for ships. The objectives of the

R&D effort were to design, develop, manufacture, and conduct at-sea trials on a superconducting coil for a shipboard MHD propulsion device. References 1-3 summarize progress through mid-1989. Successful execution of the effort has entailed the construction of new facilities for evaluation of MHD propulsion at model scale. Three facilities made of nonmagnetic, noncorroding materials, largely stainless steel, were constructed for saltwater testing at JAFSA's Tsukuba Institute: (1) a tank 23.5 m long, 3 m wide, and 2 m in depth for model MHD self-propulsion experiments; (2) a circulating water channel with a test section 5 m long, 1.6 m wide, and 1.85 m deep having a maximum flow speed of 1.5 m/s; and (3) a 1 m long, 0.1 by 0.2 m cross-section electrode testing tube having flow and speeds up to 3 m/s. These facilities have proved indispensable to the R&D efforts on MHD propulsion.

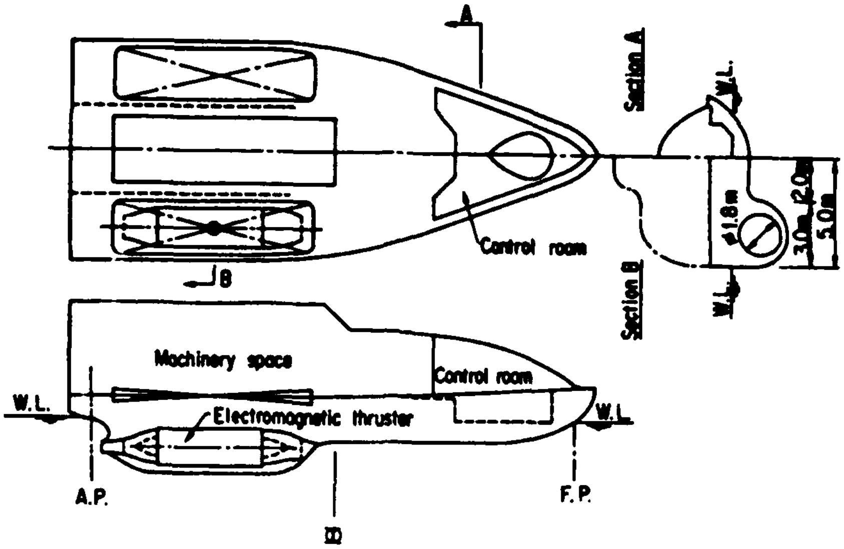
Work has proceeded on schedule with construction of a MHD propulsion vehicle to be completed by Mitsubishi Heavy Industry's Kobe Shipyard in April 1990. The at-sea evaluations of the device are planned for November 1990. The vehicle will have an aluminum hull 30 m in length with a 185-ton displacement and is predicted to have a top speed of 8 knots. Figure 1 shows an artist's picture of the vehicle and its internal arrangements. Propulsion is via twin MHD internal ducts having an estimated propulsive efficiency of less than 4 percent. The actual value will not be known until the trials are completed and many well be less than 4 percent.

MHD propulsion is based on Fleming's left-hand rule of electromagnetism applied to the magnetic field created in seawater by a magnet attached to a hull. When current flows through a coil perpendicular to the magnetic field an electromagnetic force (EMF) is created in the (weakly conducting) seawater by the interaction between the electric and magnetic fields. Propulsive thrust results from the seawater's reaction to the electromagnetic interaction. Two types of MHD propulsion were considered, external and internal. In the external version, the EMF acts on the seawater exterior to the vehicle. In the internal version, the EMF acts on seawater passing through a longitudinal duct running through the vehicle. Model experiments were conducted on both types of propulsors in 1987 at JAFSA's Tsukuba laboratory. Overall propulsive efficiencies of no more than 1 percent were achieved in these tests, which employed liquid helium to achieve superconductivity in the coils. A decision was made to adopt the internal type of MHD propulsor because it allows minimization of the amount of radiation leaked to the environment.

The twin internal MHD propulsor units adopted in the final design each consist of six dipole coils around six ducts arranged in a ring so as to reduce magnetic radiation and eliminate magnetic shielding except in way of the vehicle's control room. Electric power comes from two generators driven by two diesel engines. Reference 4 describes the experimental evaluation of the hydrodynamic performance of the propulsor units. A drawing of the propulsor cross section is shown in Figure 2 and the principal design performance measures are approximately as follows (Ref 4):

Magnetic Flux Density at Duct Center	4 tesla (T)
Normal Electrode Current	2,000 A
Total Thrust (two units)	8,000 N
Total Capacity of Main Generators	4,060 kW
Total Weight of Propulsion Equipment	130 tons

In estimating the total thrust a 50 percent efficiency was assumed for converting Lorentz force into thrust.



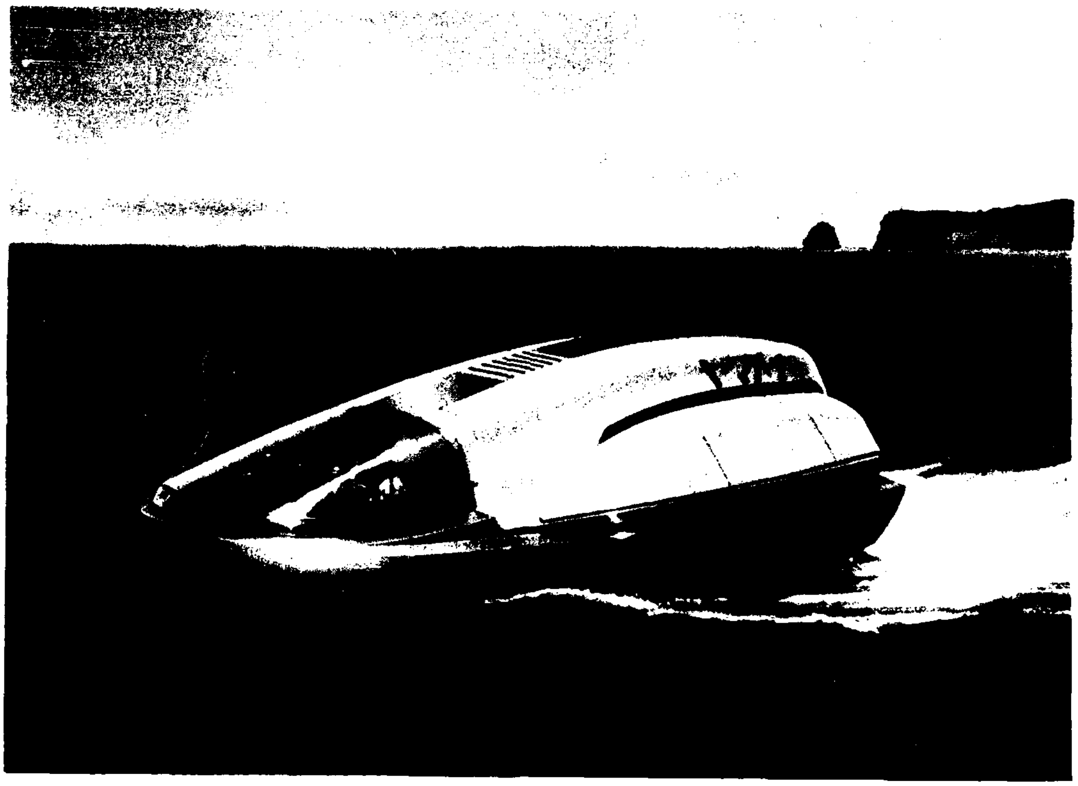


Figure 1. Experimental MHD vessel (*courtesy of Japan Foundation for Shipbuilding Advancement*).

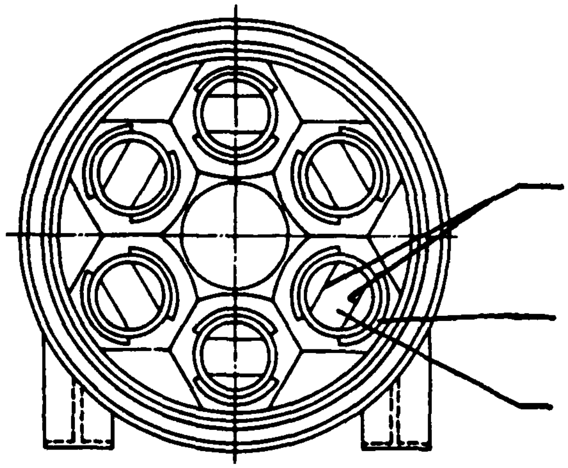


Figure 2. Six-duct MHD propulsor arrangement.

The low values of efficiency achieved to date result mainly from the Joule heating loss due to the low conductivity of seawater. Efficiency, which is directly proportional to ship speed (U) and the square of the magnetic flux density (B), can be significantly increased if much more powerful magnetic fields can be generated. A twofold increase in B from 4 to 8 T and in speed from 8 to 16 knots would result in a maximum overall propulsive efficiency of about 30 percent in comparison with the estimated maximum overall propulsive efficiency of 4 percent for the unit to be tested at sea. Thus, the development of more powerful, lightweight magnets is one of the keys to efficient and commercially economical MHD ship propulsion in the future. The availability of high temperature superconducting materials would also provide a major advance.

Other important factors affecting future viability include the choice of nonpolluting electrode materials for long life, a subject proprietary to JAFSA, and the control of bubbles and large-scale turbulence associated with the MHD process. The presence of copious amounts of bubbles and associated noise would be unacceptable in naval applications. Experimental research investigations are currently underway at JAFSA's Tsukuba laboratory to evaluate electrode materials, alternative electrode geometries, and bubble generation. The initial choice of electrode material is titanium coated with an oxide, but other materials with reduced chlorine generation are under consideration. Many difficulties have obviously presented themselves, but Japan's JAFSA leadership is continuing its significant commitment to the high-risk development of MHD propulsion.

PROPELLER BOSS CAP FIN (PBCF)

The PBCF device to increase propulsive efficiency has been developed during 3 years of collaboration between Kazuyuki Ouchi of the Mitsui OSK Lines, Ltd. and Masahiro Tamashima of the West Japan Fluid Engineering Company in Sasebo, Japan (Ref 5 and 6). The PBCF concept, depicted

in Figure 3, consists of small fins placed on the hub fairwater (boss cap) aft of the propeller. These fins are designed to reduce the swirl downstream of the propeller, thereby reducing wake kinetic energy losses and at the same time reducing the tendency for hub vortex cavitation. During the past 2 years 59 vessels, ranging in size from a 300-ton fishing boat to a 98,000-ton bulk carrier, have been fitted with PBCF devices. Depending on the ship, efficiency gains of between 2 and 8 percent have been realized in sea trials, with an average gain of about 4 percent. Model experiments have shown significant delays in the onset of hub vortex cavitation.

One of the surprises in the Japanese work has been the discrepancy between efficiency gains realized in model self-propulsion experiments and at full scale, the latter being up to 6 percentage points higher than the former. No satisfactory explanation for the difference has been found, but it is believed to be caused by Reynolds number "scale effects" between model and full-scale test conditions. Because of a factor of 100 difference in model- and full-scale Reynolds numbers, the hull boundary layer flow into the propeller will differ in the hub region and, in the case of the model, laminar flow and separation may occur on the back side of the model propeller blade near the hub. Both effects could degrade the performance of the PBCF device at model scale, but quantitative resolution of the scaling problem can be achieved only by model and ship velocity measurements in the region of the PBCF. Full-scale velocity measurements are difficult and have been conducted rarely. As a result Ouchi and Tamashima will rely simply on the empirical finding based on extensive data, that propulsive efficiency gains with a PBCF device at full scale will be about double those measured at model scale.

In order to better understand the powering performance of PBCF devices, Gearhart and McBride of the Applied Research Laboratory at Pennsylvania State University have conducted detailed model flow and powering measurements that they have theoretically analyzed (Ref 7). For the particular case examined the following ledger of PBCF effects was constructed:

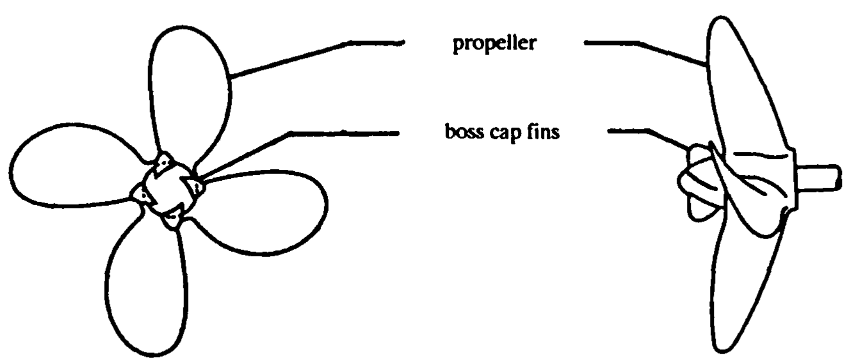


Figure 3. Propeller boss cap fin (PBCP) arrangement.

Factor	Efficiency Change (%)
Increase in thrust due to pressure rise on hub	+2
Decrease in torque due to swirl reduction	+4
Added frictional drag of PBCF vanes	-1
Net Efficiency Gain	5

As pointed out by Gearhart and McBride, the magnitude of the efficiency gain is dependent on the amount of swirl that is imparted by the propeller. Propeller designs that consider turning in the blade root sections induced by secondary flows will not have a strong root vortex and therefore will not benefit from use of a PBCF device.

CONTRAROTATING PROPELLERS

In January 1989 sea trials were successfully completed for a contrarotating propeller (CRP) system fitted to the 37,000-ton bulk carrier, *JUNO* (Ref 8). Development of this system, which entailed machinery innovations on epicyclic gears, contrarotating bearings, and seals, was initiated by Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) in 1984 in order to reduce ship fuel costs. The recent trials demonstrated a 15 percent power saving at a ship speed of 16 knots in either ballast or fully loaded conditions. As in the case of the PBCF device, the at-sea power saving was higher than had been predicted from model experiments. Additional model tests are planned to resolve the discrepancy.

A CRP system consists of two propellers on coaxial shafts that rotate in opposite directions (see Figure 4). The theoretical lifting-line methods used by IHI to design the propellers are described in References 9 and 10. The CRP concept, pioneered by John Ericsson in the mid-1800s, has long been known to provide significant efficiency gains for high-powered, single-screw ships. An American study (Ref 11) published in 1964 showed an efficiency gain of 8 percent for a CRP application to a tanker. The CRP concept can also result in reduced cavitation and propeller-induced hull vibration, and because of its smaller diameters it can be applicable to shallow draft vessels. However, because of the increased complexity, reliability problems, and cost of contrarotating shafting and machinery, there have been few applications of CRP systems to ships. Recent new gear, shafting, and seal technology advanced at IHI has removed many of the reliability concerns and it is expected that the higher initial cost of the CRP system may one day be outweighed by the fuel savings realized over the lifetime of a ship.

The features of the contrarotating gear system developed by IHI are shown in Figure 5. The system, driven by a single engine and designed to produce equal rpms and torques on the forward and aft contrarotating propellers, consists of star-compound epicyclic gears, oil lubricated roller bearings, seals, and a Geislinger elastic coupling for torsional vibration isolation. The epicyclic gear system consists of a sun gear on the inner propeller shaft that drives two planet gears in a direction opposite to the sun gear. The planet gears drive a ring gear on the outer shaft in a direction opposite to the inner shaft to produce contrarotation. The shaft-mounted gear arrangement was adopted for protection of the gears during hull deformation. IHI believes that one of the most important technical achievements is the design of the contrarotating radial roller bearing between the contrarotating

shafts. Tapered and static-pressure-type bearings were considered but rejected for a number of reasons. Prior to installation on *JUNO*, the entire CRP system was shop tested for 500 hours to confirm its expected satisfactory performance. No problems have been encountered during at-sea operations.

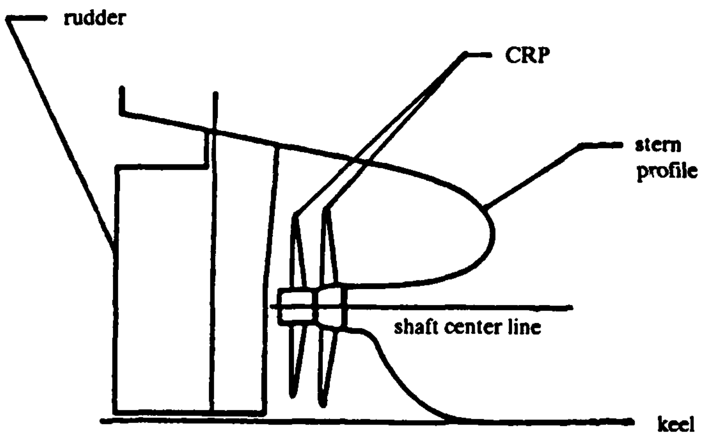


Figure 4. Stern arrangement of contrarotating propellers (CRP).

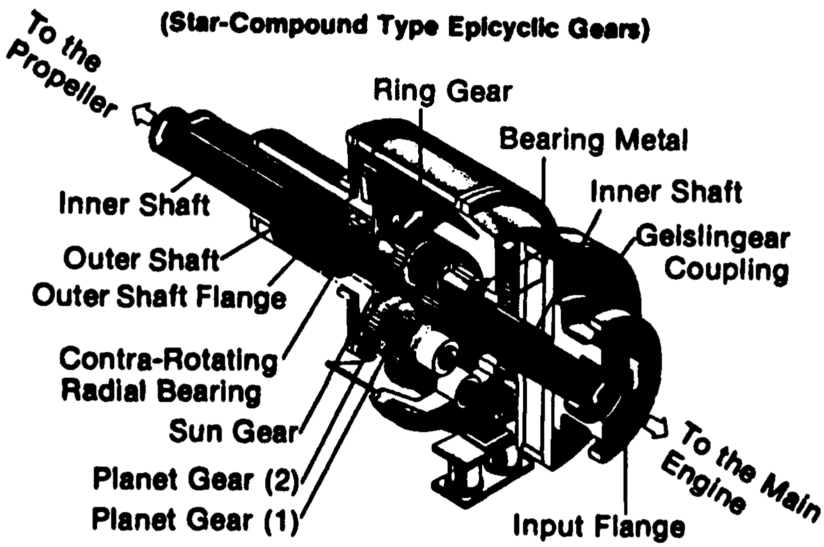


Figure 5. IHI contrarotating gear system.

SUPER HIGH-SPEED VESSEL - "Techno-Superliner '93"

An ambitious new 5-year program, initiated in April 1989 by Japan's Ministry of Transport and involving an association of Japan's principal shipbuilders and government laboratories, is aimed at developing a super high-speed vessel for transporting high value cargo (Ref 12). The vessel is called "Techno-Superliner '93" (TSL) and is to be demonstrated in 1993 on a large-scale model, from 20 to 30 m in length. The prototype TSL is projected to be put into service before the end of the century. The goals call for a 50-knot speed, 1,000-ton payload, and 500-nautical mile range. TSL is to be operable in the ocean up to sea state 6 (significant crest-to-trough wave heights up to 6 m). It is viewed as providing an alternative to airplane and merchant ship transport for carrying more lightweight cargo than planes in shorter times than ships. To set the stage for TSL a high-speed craft symposium, organized by the Society of Naval Architects of Japan, was held in June 1989 (Ref 13).

A key consideration in TSL's design is the minimization of wave making resistance by having its main hull rise above the sea surface at high operational speeds of up to 50 knots. Two types of craft are being explored. (1) In the familiar surface effect ship (SES) the hull rides on an air cushion on the water surface. The air is trapped between shallow-draft side walls and flexible skirts at the bow and stern. (2) A small waterplane area twin hull (SWATH) configuration has submerged foils that lift the main hull above the ocean surface. In this concept relatively thin vertical support struts, two on each side, pass through the ocean surface connecting the main hull to twin underwater hulls that contain the propulsion machinery and support the lifting foils. Figure 6 shows an artist's picture of this concept.

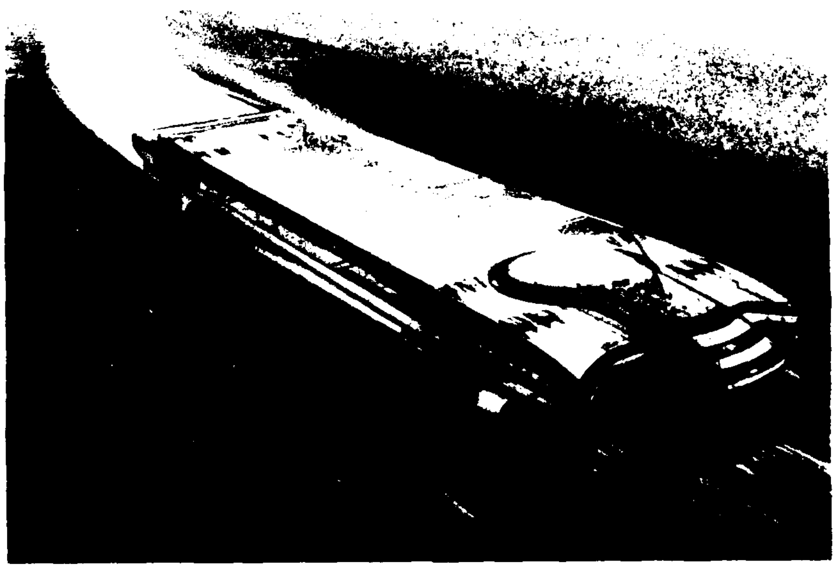


Figure 6. Techno-Superliner '93 (TSL).

The SES concept is being evaluated at Mitsubishi and Mitsui Heavy Industries; the SWATH concept is being evaluated by an association of Kawasaki, IHI, NKK, Sumitomo, and Hitachi Heavy Industries. For both hull concepts water-jet propulsion with gas turbine and/or superconducting motor drives is being considered. The first 3 years of the national effort will deal with preliminary design, hydrodynamic performance prediction, structures, (new) materials, and the propulsion system. The last 2 years will be devoted to the ride control system and a large-scale model demonstration.

If successful, the high-risk TSL effort will provide transit times of under 12 hours within Japan, between Tokyo and Kyushu or Hokkaido, and from Nagasaki to Shanghai, China. The TSL effort is sure to be followed closely by all maritime nations.

POSTSCRIPT

Three years ago I reported on two other Japanese propulsor concepts (Ref 14 and 15) that were undergoing evaluation at model scale at that time: the off-center placement of propellers on single-screw ships and the "wave-devouring propulsor" (WDP). Both concepts have been recently evaluated at sea with success, the former by NKK Corporation on a 233,000-ton ore carrier and the latter by Hitachi Zosen Corporation on a 16 m fishing vessel.

Trials for the off-center propeller, placed 1.3 m to starboard of the ship's centerline and rotating clockwise so as to oppose boundary layer vorticity rotating in a counterclockwise direction, increased propulsive efficiency to the extent that annual fuel costs will be reduced by about $75,000 (Ref 16). The second, more unorthodox, concept consists of a bow-mounted, spring-loaded horizontal foil that is tuned to oscillate when ocean waves cause the ship to pitch, generating a net thrust force on the foil and reducing the pitch motions of the ship. It is intended as an energy-saving, auxiliary propulsion device. In the recent sea trials in head seas the WDP produced a speed of about 2 knots on its own and reduced pitch motions by about 40 percent (Ref 17).

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REFERENCES

1. S. Motora, S. Takezawa, and H. Tamama, "Research and development of superconducting electromagnetic propulsion ships," *Technical Report of Tsukuba Institute* 9(1), 1-9 (April 1989).

2. S. Takezawa, "R&D superconductive electromagnetic propulsion ship," in *Advances in Superconductivity*, edited by Kitazawa and Ishiguro (Springer-Verlag, Tokyo, 1989), pp 51-54.

3. S. Motora, S. Takezawa, and H. Tamama, "Present status of the JAFSA's MHD Propulsion Ship Project," 16th Meeting of the U.S.-Japan Cooperative Program in Natural Resources/Marine Facilities Panel, Seattle, 17-18 September 1989, pp 108-113.

4. R. Tasaki, K. Sugawara, K. Miki, and R. Sato, "Design and measurement of pressure loss of junctions dividing into and combining six branches," *Technical Report of Tsukuba Institute* 9(1), 10-25 (April 1989) (in Japanese).

5. K. Ouchi, "Research and development of PBCF (propeller boss cap fin) - Improvement of flow from propeller boss," in *Proc. Int'l Symposium on Ship Resistance and Powering Performance*, Shanghai, 11-14 April 1989.

6. K. Ouchi and M. Tamashima, "Research and development of PBCF (propeller boss cap fin) - New and practical device to enhance propeller efficiency," in *Proc. PRADS Symposium*, Varna, Bulgaria, October 1989.

7. W. Gearhart, and M. McBride, "Performance assessment of propeller boss cap fin type device," in *Proc. 22nd American Towing Tank Conference*, St. Johns, Newfoundland, 8-11 August 1989.

8. "JUNO - 37,000 DWT class contra-rotating propelled vessel," *IHI Engineering Review* 22(4), 117-125 (October 1989).

9. R. Fujino et al., "A practical design method for contrarotating propeller systems," in *Proc. PRADS Symposium*, 1987, pp 110-118.

10. S.I. Ishida and R. Fujino, "A practical design procedure of contrarotating propellers," *IHI Engineering Review* 22(2), 53-59 (April 1989).

11. J.B. Hadler, W.B. Morgan, and K.A. Meyers, "Advanced propeller propulsion for high-powered single-screw ships," *Trans. Soc. of Naval Architects & Marine Engineers* 72, 231-293 (1964).

12. "R&D of super high-speed vessel started to realize creation of 'Techno-Superliner '93'," *SEA-Japan* 214 (February-March 1989).

13. "High-speed craft and its performance," in *Proc. High-Speed Craft Symposium* (Society of Naval Architects of Japan, June 1989) (in Japanese with English abstracts).

14. J.H. McCarthy, "A meeting of the Japanese ship performance committee," *ONRFE Scientific Bulletin* 11(4), 31-34 (October-December 1986).

15. J.H. McCarthy, "Three out-of-the-ordinary hydrodynamics research investigations underway in Japan," *ONRFE Scientific Bulletin* 12(2), 87-94 (April-June 1987).

16. "Maiden voyage for fuel-efficient ore-carrier," *NKK News* 29(8), 3 (October 1989).

17. Y. Terao and H. Isshiki, "Sea trial of wave devouring propulsion system," Abstract of paper for the 18th Symposium on Naval Hydrodynamics, August 1989.

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THE FIRST INTERNATIONAL MARINE BIOTECHNOLOGY CONFERENCE

Aharon Gibor

Marine biotechnology is a fast-developing enterprise. Better exploitation of existing resources and creating new and novel products from marine organisms are some of the areas that are being explored. The Japanese Society for Marine Biotechnology hosted the first international meeting devoted to this subject. Participants came from 24 countries. Fields of study ranged from microbes to mammals. A brief summary of the proceedings is presented.

INTRODUCTION

The First International Marine Biotechnology Conference, held in Tokyo on 4-6 September 1989, was sponsored by the Japanese Society for Marine Biotechnology and about 70 different companies. This new society was established in September 1987. It includes members from the academic, government, and industrial sectors. Prof. S. Miyachi, Institute of Applied Microbiology, University of Tokyo, is the chairman of the society. The international organizing committee included R. Colwell, University of Maryland; P. Gerhardt, Michigan State University; P. Lasserre, France; G.E. Allende, Chile; M. Ringpfell, East Germany; C.K. Tseng, China; and M.W. Loutit, New Zealand.

The meeting brought together several hundred scientists from around the world. The sessions were organized around four basic subjects: (1) microorganisms, (2) microalgae, (3) macroalgae, and (4) marine animals. In all, about 100 papers were presented orally, and 40 were presented as posters.

A very timely and interesting plenary session was devoted to the subject of atmospheric CO_2 and its implications to marine biotechnology. There is a universal concern with the increase in CO_2 content of the atmosphere and its ecological consequences. The ocean-atmosphere interphase constitutes three-fourths of the surface of the planet. Thus, the rate of equilibration of the atmosphere with the ocean is dependent on the rate of diffusion across this interphase. The fate of the carbon that diffuses into the surface waters of the ocean determines the concentration gradient across this interphase. Biological activities control the fate of the carbon in the ocean surface and thus are crucial to this geochemical process.

An active inorganic carbon transport system operating on the membranes of some photosynthetic algal cells was implicated in the ability of the cells to concentrate inorganic carbon from their environment. The higher concentration of inorganic carbon has a direct effect on the activities of other cellular enzymes. For example, the level of carbonic anhydrase was found to vary in response to the abundance of available CO_2,

increasing as the level of CO_2 drops (S. Miyachi, Univ. of Tokyo). The dual activities of the enzyme rubisco also vary with the concentration of CO_2. At high levels of CO_2 reduction is favored over photo-oxidation reaction. The dual action and responses of rubisco in marine algae are yet to be carefully studied. It is thus too early to evaluate the possible effects on photosynthetic efficiency of these algae by the increase in CO_2 content of the atmosphere (N.E. Tolbert, Michigan State Univ.).

The activities within the food web determine the fate of the reduced carbon; however, also significant is the deposition of intra and extracellular carbon as calcium carbonate. These calcite and aragonite particles rain down from the surface waters to be deposited onto the seafloor (M. Okazaki, Gakugei Univ., Tokyo; P. Westbroek, Leiden Univ., The Netherlands). Whether the rate of diffusion of CO_2 into the ocean would compensate for the rapid rise in atmospheric CO_2 is still being argued. In this context I was surprised that the role of the specialized living community that occupies the upper surface of the ocean, the Neuston, was not mentioned. There was a flurry of interest in the Neuston about 20 years ago and I think the time is ripe for its reawakening. It is likely that the Neuston organisms contain a high concentration of carbonic anhydrase, which will accelerate the solubilization of CO_2 across this interphase.

I did not find among the papers that were presented at the sessions that I attended many exciting or novel ideas, but I think it is worthwhile to summarize the type of work that is presently being undertaken under the title of marine biotechnology.

DISCUSSION OF CONFERENCE PAPERS

Microorganisms

Examples of the potentials for biotechnology of the microbes from extreme environments were presented. W. Reichardt (FRG) reported on the use of bacteria isolated from cold ocean waters as sources of enzymes for efficient decomposition of organic substances at low temperatures. At the other extreme the use of microbes from the deep sea hydrothermal vents as sources of enzymes was discussed by D. Prieur (CNRS, France) and Y. Sako et al. (Kyoto Univ.). Sako reported on the isolation of the enzyme PEP-carboxylase from a bacteria that was derived from a submarine thermal vent. This enzyme was optimally active at 80 °C. R. Colwell reported on the isolation of a large number of compounds from marine sponges and tunicates; these are being screened for their antitumor activity. Other reports dealt with finding of antibacterial, antiviral, or toxins produced by isolated marine microbes.

An interesting paper by K. Kogure et al. (Univ. Tokyo) addressed the question of the origin of the toxin tetrodotoxin (TTX), which is found in various marine animals and is particularly infamous in making the "puffer" fish highly toxic. Kogure et al., using a sensitive in vitro bioassay, showed that a large number of bacterial strains isolated from seawater, sea sediments, and marine animals are synthesizing TTX or related sodium-channel blocking agents. These toxins accumulate in various marine animals via the complex food web of the sea.

Other studies pointed to the value of the bacterial flora for the development and growth of fish in the larval stages (M. Maeda, Univ. of Tokyo) or adults (H. Sugita et al., Nihon Univ., Tokyo). Thus, growth was improved when bacterial strains that synthesize vitamin B12 were present.

Microalgae

Mass cultivation of microalgae for the production of specific high value substances is already a commercial enterprise in Australia and Israel. The halophilic alga *Dunaliella* is being cultivated primarily for its high content of beta-carotenes. The natural 9-cis isomer found in this organism is reported to be much more biologically active than the all-trans synthetic isomer. Conditions for maximizing pigment contents of the cells are being studied (A. Ben Amotz, Israel; M.A. & L.J. Borowitzka, Australia).

During the oil crisis there was a flurry of interest in several species of microalgae that produce and store hydrocarbons in their cells. Two Japanese laboratories are apparently still hard at work on cultivation of the green alga *Botryococcus* for the production of high quality hydrocarbons (S. Okada and K. Yamaguchi, Univ. of Tokyo; H. Iwamoto et al., Meiji Univ., Tokyo). Extracellular hydrocarbons were produced when the cultures grew on solid surfaces as colonies, but no such production occurred when they were grown suspended in medium. Although "high quality" gasoline could be produced by catalytic-cracking of these hydrocarbons, the cost of the product is still several orders of magnitude too high.

A novel approach to cultivation of carotenoids producing microalgae was presented by Y. Cohen (Israel). He cultivates the benthic biofilms of hypersaline ponds. These films are made up primarily of the cyanobacteria *Microcoleus* and a community of other microbes. The harvested bottom mat from these ponds was made up of over 25 percent polysaccharides and 2.5 percent carotenoids. Cohen works in a desert environment, where he constructed small ponds of evaporating seawater. The hypersaline brine that accumulates is overlayed with light seawater. Nutrients are supplied to the lower brine layer by a drip-irrigation system.

Cultivation of a red, single cell alga, *Porpheridium*, for the production of sulfated polysaccharides, pigments and polyunsaturated lipids was reported by S. Arad (Israel). She introduced a novel culture system of vertical polyethylene sleeves. Contamination by protozoa was still a major problem in her cultures.

M. Murakami and K. Yamaguchi (Univ. of Tokyo) found a potent antifungal agent produced by the dinoflagellate *Alexandrium hiranoi*. The substance is a polyether macrolide; it stops fungal growth at a concentration of 0.5 μg/ml and blocks the development of sea urchin embryos (the bioassay used for searching for bioactive substances) at 0.05 μg/ml.

T. Yasumoto et al. (Tohoku Univ.) isolated a number of polyethers from different dinoflagellates and measured their antifungal activity. Seven out of eight species of dinoflagellates produced significant antifungal substances. Y. Miura (Osaka Univ.) and T. Matsunaga (Tokyo Univ. of Agric. & Tech.) are also engaged in screening many strains of microalgae for production of antibiotics. Two of their strains produced yeast inhibiting substances.

Genetic manipulation techniques for microalgae were the subject of two papers. The marine unicellular blue-green alga

Synechococcus was successfully transformed by the use of the electroporation technique (H. Takeyama et al., Tokyo Univ. of Agric. & Tech.). Another paper by T. Kudo and N. Saga (Sapporo Univ.) suggests the use of antibiotic paper discs on agar plates in searching for transformed or genetically modified cells.

Solar energy-bioconversion by algae is also a viable topic of research.

Mass cultures of single cell algae as a renewable source of organic fuel were studied for a long time. A more recent approach was the possibility of producing fuels such as oxygen and hydrogen gas by photolysis of water. Conditions for the photosynthetic production of hydrogen and oxygen were investigated by E. Greenbaum (Oak Ridge National Lab). He screened a number of marine algae and found several that could produce hydrogen after a period of adaptation under dark, anaerobic, and free CO_2 incubation. G. Subramanian and D. Prabaharan (India) found pure cultures of marine blue-green algae that produce hydrogen from seawater upon illumination.

Macroalgae

Work on propagation of seaweeds and their genetic improvement by the disassociation of the tissue of these plants to cells and protoplasts is proceeding in many laboratories. The regeneration of plants from the isolated protoplasts occurs readily in some cases (*Porphyra*) but is still a problem for other algae (*Ecklonia*).

Zhang et al. reported on formation of hybrids of different varieties of *Gracilaria* with improved properties for cultivation at different locations in China. A. Miura and J.-A. Shin (Tokyo Univ. of Fisheries) reported on hybridization of *Porphyra* for improved nori production. J.P. Van der Meer (Canada) reported on genetic crosses in *Gelidium*.

Experimental modifications in the composition of cultivated algae were studied. Polysaccharides of agarophytes were studied by A.P. Kollist et al. (U.S.S.R.). M. Nishizawa (Defense Academy) and T. Hirano (Tokyo Univ. of Fisheries) attempted to cause cross linking of the algal macromolecules (agar) by ionizing radiation. I believe that they are attempting to improve the quality of their biocolloids by the cross linking treatment.

The quality of fatty acids of the brown alga Laminaria was studied by M. Honya et al. (Ishikawajima-Harima Heavy Industries). An interesting product from the red alga *Corallina*, collected from nature, was bromoperoxidase. This enzyme is interesting as a potential catalyst for halogenation of substances in industrial bioreactors (Y. Izumi et al., Kyoto Univ.).

T. Kajiwara et al. (Yamaguchi Univ.) reported on the cultivation of the green alga *Ulva*. They started with isolated protoplasts and grew dense unialgal cultures in flasks. They analyzed the culture medium and the plants for the production of volatile substances that are responsible for the typical flavor and smell of these plants. They reported that their cultured material appeared to be enriched with some specific components when compared to the plants collected from nature.

Marine Animals

Interesting reports on the genetic manipulations of cultivated fish were presented. B. Chevassus reported on the research in France. They are injecting fish eggs with plasmids that carry detectable genes.

Their expression was, however, not yet conclusively demonstrated. Chromosome manipulations, by mitotic blocking at different stages of zygote development, fertilizing UV irradiated eggs or using UV irradiated sperm for production of haploid or polyploid fish, are apparently successful.

Transgenic carp and loach were produced that contained and expressed the genes for rainbow trout growth hormones or human growth hormone. These genes were introduced in constructed plasmids and were injected into the recipient eggs. Over half of the injected eggs developed and the presence of the foreign DNA could be demonstrated in the fish. The expression of these genes could also be detected. A significant fraction of the F_1 progeny from crosses of the transgenic fish also carried the foreign DNA. The transgenic fish grew faster than their siblings (T.T. Chen et al., Univ. of Maryland). Biologically active tuna growth hormone was produced in *E. coli* and in yeast by recombinant DNA techniques (M. Nonaka et al., Taiyo Fishery, Tokyo). Carp alpha-globin genes were introduced into rainbow trout (T. Oshiro et. al., Tokyo Univ. of Fisheries). Direct injection of cloned genes into the nuclei of the Medaka eggs served as a model system for genetic manipulations of fish by several groups (E. Tamiya et al., Univ. of Tokyo; K. Inoue et al., Nippon Suisan Kaisha; and K. Ozato et al., Kyoto Univ.).

The uptake by rainbow trout of intestinally administered salmon growth hormone was demonstrated (S. Moriyama et al., Kitasato Univ.), and the use of hormones for improving and inducing breeding behavior in cultured fish was reported (J.M. Little and J.A. Dawson, Canada).

M. Maeda (Univ. of Tokyo) and H. Sugita et al. (Nihon Univ., Tokyo) report that the bacterial flora of fish intestines contribute to their well-being, which suggests the possibility of introducing genetically engineered bacteria with desired properties to cultivated fish.

Monoclonal antibodies were produced as vaccines to immunize cultured fish against viral infection and also for diagnostic purposes (A. Renard et al., Belgium; Y. Kamei et al., Sapporo Breweries Co., Tokyo).

Several papers reported on marine invertebrate animals as sources of cytotoxic antifungal and antibiotic substances (M. Guyot, CNRS, France; R.J. Quinn et al., Australia; and C. Del-Rio E. et al., Mexico).

FINAL REMARKS

The important value of this conference was in bringing into focus the state of the art in marine biotechnology. Most impressive was the progress reported by fish culturists in utilizing the developments of molecular biology. Immunological and recombinant DNA techniques are rapidly incorporated into this technology. The conference should also be viewed in the broader context of the increased interest, especially in Japan, in marine biotechnology. The Japanese Government, in cooperation with major industries, is now constructing two major research centers devoted to the development of marine biotechnology, one at Shimizu in Shizuoka Prefecture and the other at Kamaishi in Iwate Prefecture. The focus of the research will be: (1) identification and production of new products

from marine organisms, (2) the propagation of useful marine organisms, and (3) the control of the marine environment from man-made pollutants. The obvious dependence of the Japanese economy and the diet on the ocean is the natural driving force behind this increased interest in marine biotechnology. I foresee rapid developments in marine biotechnology, especially in Japan, in the near future.

Aharon Gibor began a 1-year assignment at the Office of Naval Research Far East in August 1989. Dr. Gibor is a professor of biology at the University of California, Santa Barbara and is now on a leave of absence from that institution. He received a B.A. degree in 1950, his M.A. degree in 1952 from the University of California, Berkeley, and his Ph.D. degree in 1956 from Stanford University. His thesis research was done at the Hopkins Marine Station. Dr. Gibor was involved in research on the genetic autonomy of cytoplasmic organelles of eukaryotic cells, especially chloroplasts and flagella. His present research is on the growth and development of algal cells and tissues and the role of cell walls of these plants in controlling their development.

FIFTH INTERNATIONAL CONFERENCE ON NUMERICAL SHIP HYDRODYNAMICS

Edwin P. Rood

It was clear from the papers presented at this conference that there has been a world-wide attempt to apply supercomputers to prediction of ship hydrodynamics, both in the numerical prediction of the flow and in the processing of large volumes of experimentally acquired data. In this sense the conference was addressed toward resolving a technology issue of solving complex hydrodynamics with brute force computer power.

This international conference was the fifth in a series that has included meetings in the United States and in France. The conference was sponsored by the Shipbuilding Research Association of Japan, the David Taylor Research Center, the Office of Naval Research, and the Naval Studies Board. Attendance at this meeting in Japan was excellent: almost 200 attendees from approximately 20 countries. There were 43 papers, with 4 invited, dealing with all aspects of numerical ship hydrodynamics. The conference is scheduled to be held again in 1993 in the United States.

There were several topics addressed in the sessions, including Navier-Stokes solvers, turbulence simulation, viscous flows, free surface waves, effects of surface tension, and image processing. It was clear from the presented papers that there has been a world-wide attempt to apply supercomputers to prediction of ship hydrodynamics, both in the numerical prediction of the flow and in the processing of large volumes of experimentally acquired data. Although there was no formally stated theme for the conference, it is easy to imagine that the theme could have been "Where are we with supercomputers?" In this sense the conference was addressed toward resolving a technology issue of solving complex hydrodynamics with brute force computer power.

Why is there a focused effort on numerical ship hydrodynamics? This seems at odds with the notion that naval hydrodynamics is a conservative field with the image of being mature. Perhaps this notion is true in the context of the design of ships to meet the current commercial demands for powering and motions. However, the technology does not permit predictions outside of the historical design parameter space, and surely does not render even a good guess at the real fluid details of the flow around marine vehicles. This latter need is in response to recent developments in remote sensing, which is anticipated to permit world-wide monitoring of maritime traffic in the foreseeable future. The advent of supercomputers has had a measurable effect on hydrodynamic predictions that has nevertheless been insignificant for design usage. More specifically, supercomputers permit calculations for much more complex geometries, but the lack of

physics in the governing equations renders those sophisticated predictions not any more useful than simpler predictions. Where will the state of the art be in the future? Supercomputers have another function, and that is to permit the large data volume analysis from image processing of whole flow field measurements. This much neeued information will permit identification and understanding of the physics required to produce accurate numerical predictions, also obtained with the supercomputer.

Chief among the needed physics are understanding and prediction of the momentum exchanges produced by three-dimensional flow separations, a predominant feature of real ship flows about hulls and propellers, and understanding and prediction of turbulent flows at free surfaces, a topical area about which there is very little understanding. The phenomena associated with the postbreaking wave, for which there is no identification of the physical mechanisms producing bubbles and vorticity, also merit scientific study. Basic research is proceeding, chiefly in the United States for the Navy, at a low level in all these areas.

This, then, is the technological challenge of the future: to apply newly emerging scientific information to the supercomputer prediction of ship hydrodynamics in an efficient manner. The field is ripe for breakthroughs in the scientific understanding of real flows because of new measurement and prediction techniques made possible by the supercomputer. These breakthroughs will provide information important not only to ship hydrodynamics but also to such related fields as physical oceanography.

Unfortunately, there was no significant new science presented at the meeting. This is not because of a lack of interest but because of the urgency to apply supercomputers to brute force computations in the recent past and because of a lack of long-term financial commitments to approach the science issues with the emerging new capabilities in instrumentation. Image processing is the single most important capability to enter the scene. It is still in its developmental stage and will prove to be a great advantage, especially when used in conjunction with supercomputer numerical predictions to guide exploration of the flow.

The conference is a hallmark and archival in its confirmation that *science* is required before supercomputer numerical prediction capability can be fully utilized.

Exemplicative papers in support of the above conclusions were presented by K. Mori et al. ("Development of a New Velocity Measurement System by Using Computerized Flow Visualization and Numerical Modelling"), T. Hino ("Computation of a Free Surface Flow Around an Advancing Ship by the Navier-Stokes Equations"), W. Saric ("Boundary-Layer Stability and Transition"), and S.A. Orszag et al. ("RNG Modeling Techniques of Complex Turbulent Flows"). The following provide brief glimpses at the significant results from these papers.

Mori has completed a preliminary endeavor to closely couple physical and numerical experiments *on line*. He makes full flow field measurements with image processing techniques, uses the processed velocities to validate numerical predictions of the measured flow field, then uses the numerical procedure to predict the flow in the regions difficult to measure. This approach is a significant change in strategy and heralds the future for predictions of complex flows. The essential element is the reliance on numerical hydrodynamics with the presumption that the reliance on physical data will decrease with sophistication in the numerical experiments.

Hino consumed some 70 hours of supercomputer time to calculate the nonlinear free surface flow around an advancing ship, and even then the geometry was relatively simple. His calculations were significant in including the defining grid for the free surface position as part of the solution. The gross features of the flow were predicted adequately, but the details of the wake were poor.

Saric summarized recent advances in understanding the physical mechanisms of boundary layer transition. It is now recognized that the flow must be considered as an open system possibly modelled by dynamical systems theory. The implication is that secondary stability analysis and subharmonic dynamics may characterize the transition process. Understanding of this process is important for ship flows around appendages and other geometries of relatively low dimensional magnitude.

Orszag presented the case for renormalization group theory as a tool for turbulence modelling. This theory provides an analytical method to eliminate small scales from the Navier-Stokes equations, thus leading to a dynamically consistent description of the large scales. The method has worked for channel flows, cavities, and backward-facing steps. The need in ship hydrodynamics is for a model of three-dimensional separation and for a turbulence expression for the wake near the free surface.

There are numerous other papers of high quality from this conference; the above examples show the relevance and timeliness of the conference as a whole.

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FIFTH INTERNATIONAL CONFERENCE ON NUMERICAL SHIP HYDRODYNAMICS: VISCOUS-FLOW PAPERS

Frederick Stern

The conference, held in Hiroshima, Japan, focused on the latest developments in numerical ship hydrodynamics, including the topics of viscous flow, wavy-inviscid flow, image processing, and cavitation. In addition, an International Towing Tank Conference (ITTC) workshop on computational fluid dynamics validation and group discussions on Rankine-source methods, Navier-Stokes solvers, and boundary-integral methods for radiation-diffraction problems were held. This report focuses primarily on the topic of viscous flow with some brief comments on the topics of image processing and cavitation and on the ITTC workshop and Navier-Stokes solver group discussion.

INTRODUCTION

The Fifth International Conference on Numerical Ship Hydrodynamics (ICNSH) was held in Hiroshima, Japan, on 25-28 September 1989. Previous conferences were held in 1985 (Washington, DC); 1981 (Paris, France); 1977 (Berkeley, CA); and 1975 (Gaithersburg, MD). Hiroshima had 189 participants representing 18 different nations. Out of these, 39 percent were from outside Japan. The United States had 18 representatives. There were 50 papers, including 5 keynote lectures, held in 11 sessions of which all but 3 were double format. The topics included viscous flow (Reynolds-averaged Navier-Stokes solvers, large-eddy simulation, free-surface effects, and unsteady flow), wavy-inviscid flow (Neumann-Kelvin formulations, body motions, radiation-diffraction problems, and Rankine-source methods), image processing, and cavitation. In addition, an International Towing Tank Conference (ITTC) workshop on computational fluid dynamics validation and group discussions on Rankine-source methods, Navier-Stokes solvers, and boundary-integral methods for radiation-diffraction problems were held. The conference was very well organized with a balanced social program that stimulated technical exchanges. However, the double session format, which was introduced for the first time, restricted attendee participation in the various topics. This report focuses primarily on the topic of viscous flow with some brief comments on the topics of image processing and cavitation and on the ITTC workshop and Navier-Stokes solver group discussion. Many, but not all, of the viscous-flow papers will be discussed.

VISCOUS FLOW

The viscous-flow papers were well representative of the present state-of-the-art both from the standpoint of accomplishments and dilemmas. Considerably more papers were presented on this topic than in previous conferences which, no doubt, is an indication of the shift of interest of ship hydrodynamics researchers towards viscous-flow methods. The status of the viscous-flow methods is such that practical ship geometries can be considered, including complexities such as appendages and propellers. Comparisons with experimental data indicate that many features of the flow are adequately simulated; however, turbulence modeling and grid generation appear to be pacesetting issues with regard to future developments. Only very limited work is being done with regard to unsteady flow and the inclusion of free-surface effects. An important general observation is that many of the authors presented their methods and computer programs as if they were completely unique and original when, in fact, they were not. Authors should provide information concerning the history of the computer programs they are using (i.e., original developer and previous applications) as well as the specific modifications and extensions that they may have made for their application. This will facilitate the assessment of their specific advancements and difficulties. In most cases, the contributions are, no doubt, significant but difficult to assess due to the lack of such information.

In general, the viscous-flow methods presented at the conference can be conveniently divided into three groups depending on the type of velocity-pressure approach used: pseudo-compressibility approach (PC), uncoupled momentum and continuity equations approach (UMC), and coupled momentum and continuity equations approach (CMC). Although finer divisions are possible, e.g., with regard to discretization techniques, turbulence models, grid-generation techniques, and other numerical procedures, these are, in most cases, relatively minor and the details of which are beyond the scope of this report. There was only one CMC method, i.e., Hoekstra. In most cases, the UMC methods used either the SIMPLE(R) or MAC (i.e., Poisson equation) algorithms. In the former case, either finite-volume (FV) or finite-analytic (FA) discretization techniques were used, whereas in the latter cases the overall numerics closely followed the standard MAC methods. The UMC-SIMPLE-FV codes closely followed the Patanker model, and the UMC-SIMPLE-FA codes closely followed the Iowa model.

Most of the papers reported results for bare bodies with applications for the Wigley, Series 60 C_B = .6, HSVA, or SSPA hull forms: Kodama (PC); Hoekstra (CMC); Zhu et al. (UMC, MAC); Oh et al. (UMC, SIMPLE, FV); Larsson et al. (UMC, SIMPLE, FA); Masuko and Ogiwara (UMC, SIMPLE, FV); Piquet and Visonneau (UMC, PISO, FA); and Tzabiras and Loukakis (UMC, SIMPLE, FV). The differences in the results between these various methods are not profound, which supports the previous status statement. Interestingly, the full transformation used by Larsson et al. and the inclusion of the near-wall turbulence model by Piquet and Visonneau do not lead to significant improvements, at least for the present applications. In the latter case, the inclusion of the near-wall model slowed convergence such that the SIMPLE algorithm was abandoned in favor of the

PISO algorithm. Tzabiras and Loukakis include results for full-scale Reynolds numbers.

Fujii's keynote lecture provided a good overview of the status of viscous-flow computations for aerodynamic applications. Although the magnitude of the effort is considerably larger, the status of this work appears to be the same as that stated previously for ship hydrodynamics. Yang et al. (PC) report results for axisymmetric bodies, including investigations of angle of attack (separated flow) and propeller-hull interaction. The propeller-hull interaction work closely follows the earlier work of Stern and Kim. Hino (UMC, MAC) investigated free-surface effects using a method that closely follows the MAC and SUMMAC methods; however, extensions were made for body-fitted coordinates and high Reynolds numbers and an approximate method is used whereby the grid is fixed and does not conform to the free surface. The results are promising but clearly have difficulty in accurately resolving the boundary layer and wake. Kinoshita et al. (UMC, MAC) investigated oscillatory flow around a circular cylinder. The results are in close agreement with available experimental data. Stern and Kim (UMC, SIMPLE, FA) significantly extended their previous work on propeller-hull interaction to a "complete" viscous-solution method for marine propellers. Results are presented for an idealized geometry that exhibits many of the distinctive features of interest.

Lastly, with regard to the viscous-flow papers, the keynote lectures of Saric and Orszag et al. were valuable in providing to the ship hydrodynamics community current information on boundary-layer stability and transition and RNG and spectral methods, respectively. In the former case, recent work indicates that there is some hope for a useful stability and transition theory, whereas in the latter case, it appears that such methods may find application in ship hydrodynamics. Doi presented results for turbulent channel flow using a large-eddy simulation, finite-difference method. The finite-difference scheme appears to attenuate the turbulence intensities in comparison with the results from other methods.

IMAGE PROCESSING AND CAVITATION

The two papers on image processing, Mori and Ninomiya and Fu et al., were interesting and generated considerable discussion. The latter approach appears very promising for quantitative measurements. Kubota et al. presented an innovative approach to the problem of bubble cavitation in which both the fluid and bubbles are treated as a continuum of a compressible viscous fluid with a large density variation. The results reproduce some of the observed trends. Kinnas and Fine presented an "alternative" linearized supercavitating foil method that allows for leading edge, face, and mid-chord detachment as well as partial cavitation. The method is applied for a foil and in a quasi-steady manner for unsteady propeller cavitation.

CONCLUDING REMARKS

Although vigorous discussions were held in the ITTC workshop concerning computational fluid dynamics validation, it appears that a consensus of opinion is unobtainable in the near future. This is not surprising in consideration of the difficulty

of validation even for experimentation and the fact that uniqueness theorems do not exist for the solutions to the governing equations of computational fluid dynamics. The Navier-Stokes solver group discussion was directed towards a developers and users forum on issues related to computer program development; however, as discussed earlier, in order to successfully hold such a forum, the various methods being discussed must be properly categorized.

In summary, the Fifth ICNSH was a very successful conference and provided a useful exchange of technology.

Frederick Stern received his Ph.D. in naval architecture and marine engineering from the University of Michigan in 1980. Subsequently, he worked as a research naval architect at Science Applications, Inc., Annapolis, MD, until September 1983, whereupon he assumed his present position as Associate Professor of Mechanical Engineering and Research Engineer at the Iowa Institute of Hydraulic Research, The University of Iowa. His research interests are in ship hydrodynamics, including viscous flow, propellers and cavitation, potential flow, drag prediction, and ship and platform dynamics. Professor Stern is a member of SNAME, ASME, and ASEE.

TURBULENCE MODELING IN JAPAN

Hideo Yoshihara

Significant research on turbulence modeling for Reynolds-averaged Navier/Stokes equations in Japan is reviewed. Anisotropic k,e models and large eddy simulation studies are covered.

INTRODUCTION

In aerospace applications the Reynolds-averaged Navier/Stokes equations with eddy diffusivity turbulence models are used almost exclusively. The simplest of these turbulence models, such as the Cebeci/Smith or Baldwin/Lomax algebraic mixing length models, have yielded satisfactory solutions in many cases. There are, however, many key flows for which the algebraic turbulence models have been seriously deficient. One such case of importance is the strong shock/boundary layer interaction with post-shock separation arising, for example, on a swept wing at transonic speeds. Here the failing in part stems from the assumption of local equilibrium for the turbulent transport where the local transport is taken independent of its prior history. For swept shock separations arising on a swept wing, the turbulent transport becomes strongly dependent on the crossflow with the streamwise Reynolds stress significantly decreased by the crossflow. For swept-shock/boundary layer interactions, both prior history as well as crossflow effects must be incorporated into the turbulence model. For flows with significant secondary flow as in the separated region of a backward-facing step, in a rectangular duct, or in the wing/fuselage juncture region, assumption of isotropy of the turbulence transport ceases to be valid. There are also flows in which the turbulent transport is locally in equilibrium but the mixing length cannot be suitably defined as in a confluent boundary layer on a flapped wing. In some cases a mixing length can be defined, but its determination becomes unwieldy as in an unstructured or irregularly defined grid. In these cases one must turn to differential equation turbulence models.

In Japan there are several efforts that address some of the above shortcomings. In the following sections, recent efforts on anisotropic k,e models and large eddy simulation calculations are described and some miscellaneous results on other modeling studies are presented.

TWO-EQUATION k,e TURBULENCE MODELS

The k,e model lies in the next level of the eddy diffusivity hierarchy from the algebraic models. The characteristic velocity and length scales are defined by partial differential equations for the turbulent energy (k) and dissipation length scale (e). For secondary flows in the separated region of a backward-facing step and in a corner of a rectangular duct or along the wing/fuselage

juncture, the standard isotropic k,e method is inapplicable. An anisotropic model is required as developed by Yoshizawa (Ref 1), which was described earlier (Ref 2). This model was derived using Kraichnan's Direct Interaction Approximation assuming the turbulence to be a dichotomy of large and small eddies widely separated in scale. Such a model is valid only for large Reynolds numbers and is inapplicable in the low Reynolds number region close to the wall where important practical effects of turbulent transport occur. A Van Driest-type damping function was used as an expedient to bridge the near-wall region.

Nisizima and Yoshizawa (Ref 3) applied the anisotropic model to a Couette flow at a Reynolds number of 14,000 (based on channel half-width and wall velocity) and a fully developed planar channel flow at Reynolds numbers of 12,704 and 32,637 (based on channel half-width and centerline velocity). Test/theory match in these cases was mixed. In both flows the agreement of the mean velocity distributions across the channel, in particular the velocity profiles near the wall, was excellent. Test/theory agreement of the turbulent intensities and Reynolds stress, hence the anisotropy, was reasonably good across most of the channel, but discrepancies occurred near the wall. Test/theory comparison was found to be qualitatively the same for the turbulent energy and the dissipation. In summary, incorporation of the anisotropy greatly improved the test/theory agreement relative to the isotropic model for both the Couette and planar channel flows.

Eddy diffusivity modeling for the above planar channel flow is "one dimensional." The square duct flow is a "two-dimensional" modeling problem and is thus significantly more difficult. In Reference 4 Nisizima and Yoshizawa, using the above anisotropic k,e model, calculated the fully developed square duct flow for a Reynolds number of 43,379 based on the bulk velocity and the duct width. For the damping function a product of the single-wall damping functions was assumed. The calculations were carried out by a finite difference method for the Navier/Stokes equations expressed in terms of a stream function. Calculations were compared with several sets of experimental data. Data at the computed Reynolds number were taken from Reference 5. Other data at a significantly different Reynolds number were used only for qualitative comparison purposes. Data were presented as contour maps in a cross-sectional plane. The streamwise and crossflow mean velocities, mean crossflow velocity vectors (to show secondary vortical flows), turbulent intensities and Reynolds stress (to show anisotropy), and the turbulent energy were plotted. In general, the computed contour lines for the above quantities showed the same topological features as the experiments, but there were significant quantitative differences, particularly in the corner region where the calculations are unreliable. The authors also suggested that a partial cause for the significant test/theory mismatch was due to the experimental duct flow not being fully developed. The location of the secondary flow vortices agreed reasonably with experiments.

IMPROVED k,e METHOD OF MYONG AND KASAGI

The primary contribution of Myong and Kasagi (Ref 6) was to extend the anisotropic k,e model of the type developed by Nisizima and Yoshizawa to cover the near-wall region. This was accomplished in two steps. First, the standard isotropic model was extended into the near-wall region by

introducing a new near-wall characteristic length scale. The latter incorporated the influence of viscosity and the proper near-wall behavior of the velocity fluctuation components. A composite dissipation length scale was then formed as the sum of the near-wall length scale and the outer flow length scale from the standard isotropic model. The sum was multiplied by a Van Driest-type damping function. The above composite length scale was suggested earlier by Rotta (Ref 7). The second step was to incorporate anisotropy by postulating two quadratic mean velocity gradient terms to be added to the Reynolds stress tensor equation. The first term was essentially that derived by Yoshizawa, while the second resulted from the anisotropic diffusion term in the turbulent energy equation. The latter term has an essential contribution in the near-wall region but is negligible elsewhere.

The improved anisotropic k,e method was applied to the fully developed planar channel flow at Reynolds numbers (based on centerline velocity) of 5,580, 27,600, and 100,000 using the finite volume time-marching method of Patankar. With the exception of the turbulent energy, the test/theory match of the mean velocity, turbulence intensities, normal and Reynolds stresses, and dissipation was excellent. In the case of the turbulent energy, there was a nonnegligible test/theory mismatch in the peak region near the wall. It was suggested that the cause was due to an erroneous measurement of the streamwise turbulence intensity. The computed results also agreed closely with the direct simulation calculations of Kim, Moin, and Moser (Ref 8) at the lowest Reynolds number of 5,580.

Myong and Kobayashi (Ref 9) more recently used the above improved k,e method to calculate the flow in a finite square duct at a Reynolds number based on bulk velocity and duct width of 25,000. The product of the single-wall damping functions was used. The calculated results were compared to the experimental results of Gessner and Emery (Ref 10). The addition of the near-wall improvement led to a good overall test/theory match. The streamwise and lateral distributions of the mean streamwise velocity component showed excellent agreement. The agreement of the mean crossflow velocity was, however, less satisfactory, while the distributions of the turbulent energy and the Reynolds stress across the duct compared reasonably with experiments. There were discrepancies in the wall shear in the corner region, but this should not be surprising in view of the unproven two-dimensional damping function that was assumed. In summary, the results from the improved k,e method of Myong and Kasagi yielded greatly improved test/theory agreement with little added complexity over the standard isotropic model.

LARGE EDDY SIMULATION (LES)

In a direct simulation of turbulent flow the unsteady Navier/Stokes equations are solved using a sufficiently refined mesh and time step to resolve the turbulent fluctuations. To reduce the space/time resolution requirements, in LES a filter is applied to the Navier/Stokes equations to screen out the high frequency end of the fluctuations. The well-known difficulty arising by the filtering is that a subgrid scale viscosity appears in the momentum equations to render the system of equations underdetermined. The key problem in LES is the modeling of the subgrid scale viscosity. In the following, the recent research of Horiuti (Ref 11) and Miyake and Kajishima (Ref 12) for a planar channel flow is described.

LES Calculations of Horiuti

The subgrid scale viscosity is given by the sum of three contributions, namely, the Leonard term, cross-stress term, and the Reynolds stress term. In an earlier contribution (Ref 13) Horiuti, in a LES calculation of a fully developed planar channel flow, confirmed that the Leonard and cross-stress terms were essentially equal but of opposite sign, so that the previous practice of neglecting only the cross-stress term would lead to substantial deterioration of the result. He further showed that the use of Bardina's expression for the cross-stress and Reynolds stress term led to improved LES results. It also restored Galilean invariance, though this is not a factor in a fully developed channel flow. More recently Horiuti (Ref 11) implemented the Bardina model in a finite difference method. By suitably formulating the differencing of the Leonard and cross-stress terms, the anisotropic form of the subgrid scale viscosity due to Yoshizawa (Ref 14) was evolved through the quadratic truncation error term. Of special interest was the "side-by-side" calculation of the planar channel flow with the direct simulation and LES methods. The direct simulation result was then filtered and compared to the LES solution. Correlation of the two solutions in terms of the streamwise fluctuation velocity averaged over the channel width was of the order of 0.75 across the channel. Computing time with the new difference procedure was half of that of the fully spectral method.

LES Calculations of Miyake and Kajishima

Calculations were carried out for a fully developed planar channel flow at a Reynolds number of 4,940 based on bulk velocity and channel height (Ref 12). The mesh dimensions were 256 (streamwise), 117 (normal), 128 (spanwise) for a total of 3.83×10^6 mesh points. (This compares to a mesh dimension $192 \times 129 \times 160$ with a total number of points of 4×10^6 points in the direct simulation calculations of Kim, Moin, and Moser (Ref 8), who used a fully spectral method.) The Smagorinsky model was used for the subgrid viscosity. Finite differencing was employed in the normal direction. Three cases considered were the steady channel flow, a channel flow rotating about an axis normal to the walls, and a steady channel flow with sinusoidal streamwise area variations. In the basic channel flow good agreement was achieved with the direct simulation results of Mansour, Kim, and Moin (Ref 15) for the mean distance between streaks, location of the turbulent energy peaks, and other statistical quantities as flatness and skewness factors. Good agreement with the direct simulation results confirmed effects of the Smagorinsky viscosity, required for stability, to be negligible.

Miyake and Kajishima used their LES solution to assess Launder's model of the redistribution terms and Hanjalic's isotropic model for the dissipation term used in the Reynolds stress turbulence model. The result was that the above models were reasonable in the core portion of the duct, but they failed badly near the walls. The authors suggested a need to incorporate some aspects of the coherent streak structure into the modeling.

In the rotating channel, the effect of the Coriolis force was correctly reproduced with Reynolds stress amplification occurring on the pressure side and its suppression on the suction side. At a sufficiently large rotation rate a near-relaminarization occurred on the suction side, but this flow was distorted since the Smagorinsky subgrid

viscosity could not be conveniently turned off. In the wavy wall calculation a sinusoidal porous wall condition was prescribed on one wall. Periodic boundary conditions were retained in the streamwise direction. The results confirmed that the turbulence intensities were increased in the decelerating region and decreased in the accelerating region.

MISCELLANEOUS TURBULENCE MODELING STUDIES

Exploratory Turbulence Modeling Studies on Practical Configurations

Takakura, Ogawa, and Ishiguro (Ref 16) recently reported on an exploratory study of several current turbulence models for strong shock/boundary layer interaction on the ONERA-M6 wing where shock-induced separation was present. An ADI Navier/Stokes method in the delta formulation was used, and the turbulence models investigated were the widely used algebraic Baldwin/Lomax model, the standard isotropic k,e model, and the Smagorinsky subgrid model used in large eddy simulation. The use of the latter is surprising and inappropriate since the subgrid model is intended to model only the effects of the smallest eddies, so that significantly finer mesh and shorter time step must be used than required for the Reynolds-averaged simulation.

On the M6 wing the shock configuration at the computed Mach number and angle of attack was a lambda planform shock composed of a swept forward shock and essentially unswept rear and outboard shocks. Shock-induced separation occurred downstream of the outboard shock. Calculated results showed a significant improvement in the test/theory match of the chordwise pressure distributions with the k,e model relative to the Baldwin/Lomax model, particularly in the important outboard shock region where separation occurred. The k,e model was, however, still inadequate for the shock/boundary layer interaction, producing shock pressure-rises that were too large, leading to a shock location that was too far aft. The shortcoming of the standard k,e method is primarily due to the assumption of isotropy, where significant crossflow effects on the turbulent transport are omitted in the interaction region. Crossflow here is essentially spanwise, reducing substantially the streamwise Reynolds stress. This decrease produces a greater wedging displacement effect of the boundary layer at the shock which, then, produces the needed smaller shock pressure-rise and, more importantly, the proper upstream displacement of the shock.

Another illustrative Navier/Stokes calculations is that of Sawada (Ref 17) on the Japanese space shuttle HOPE configuration at $M = 3.5$ and 10° angle of attack. The mesh was generated by a multi-block system using an algebraic method. With this method mesh anomalies arose in the form of "fictitious corners" at the vehicle surface where the "normal" coordinate in a cross-sectional plane switched coordinate families. This complicated the determination of the mixing length, necessitating use of a differential equation model, in this case Coakley's q,w two-equation model. Here the algebraic Baldwin/Lomax turbulence would have sufficed if the mesh anomalies were absent. Thus, if a more appropriate mesh generation scheme were employed for the relatively simple shuttle configuration considered, the much simpler Baldwin/Lomax algebraic turbulence model could have been used as was done, for example, by

Yamamoto, Suzuki, and Mori (Ref 18). Stiffness effects of the turbulence equations arising via the nonhomogeneous terms were circumvented by taking a sufficiently small marching step.

Large-Scale "Direct Simulation"

In the direct simulation of turbulence the mesh must be sufficiently refined and the time step sufficiently short that the important scales of turbulence are resolved. The consequence of an inadequate mesh and time step is that truncation errors will appear that distort the turbulence. In a number of papers (e.g., Ref 19) Kuwahara and his colleagues assumed that the large-scale unsteady portion of the flow as the wake of a bluff body could be simulated by the Navier/Stokes equations without resolving the small-scale turbulence. That this is erroneous can be shown by considering the simple case of a circular cylinder. Here it is known that the location of the separation point and the rate of vorticity shed along the separation streamline are directly dependent on the nature of the boundary layer just upstream of the separation point. If the mesh and time step are inadequate, the correct character of the boundary layer upstream of the separation point would not be properly simulated. As a result the separation point and vorticity shed would be erroneous, thus distorting the large-scale wake flow.

SUMMARY AND CONCLUSIONS

Unquestionably outstanding research on turbulence modeling is being carried out in Japan. Professors Yoshizawa, Miyake, and Kasagi and Dr. Horiuti would certainly rank in the top levels of competence in the United States. They are well supported by the Ministry of Education, Culture, and Science in terms of research staff and computer support. It is also true that centers of turbulence modeling are few in number in Japan, at least an order of magnitude fewer than in the United States.

The basic understanding of turbulence has advanced significantly, particularly through direct simulation calculations as those described above. Needs of the applied computational fluid dynamicist, however, are not much closer to being met. Thus consider the relatively simple case of the corner flow where "overlapping" boundary layers occur. The anisotropic k,e model of Myong and Kasagi greatly improved the prediction of the secondary flow in the square duct. In a more severe corner flow as in the wing/fuselage juncture in which a strong separation vortex is embedded, there will not be a tolerance to a corner damping function as in the square channel case. It is not clear whether renormalization group theory of turbulence might not provide a viable transport model free of unphysical corner damping functions.

Turbulence modeling for shock-induced separation downstream of a swept shock is of a much greater complexity. Existing modeling approaches as those described above are inadequate. Modeling the dependence of turbulent transport on the cross-flow in this situation can only proceed phenomenologically.

REFERENCES

1. A. Yoshizawa, "Statistical analysis of the deviation of the Reynolds stress from its eddy-viscosity representation," *Physics of Fluids* 27 (1984).

2. H. Yoshihara, "Turbulent flow simulation research in Japan," *Scientific Information Bulletin* 14(1), 99-106 (1989).

3. S. Nisizima and A. Yoshizawa, "Turbulent channel and Couette flows using an anisotropic k-e model," *AIAA Journal* 25(3) (1987).

4. S. Nisizima and A. Yoshizawa, A numerical study of turbulent square-duct flow using an anisotropic k-e model, University of Tokyo (Seiken) Informal Report (1989).

5. A. Melling and J. Whitelaw, "Turbulent flow in a rectangular duct," *Journal of Fluid Dynamics* 78 (1976).

6. H. Myong and N. Kasagi, "Toward an anisotropic k-e turbulence model taking into account the wall-limiting behavior of turbulence," *Proceedings ISCFD Nagoya* (1989).

7. J.C. Rotta, Statistical theory of non-homogeneous turbulence, Imperial College Report TWF/TN/39 (1968).

8. J. Kim, P. Moin, and R. Moser, "Turbulence in channel flow at low Reynolds number," *Journal of Fluid Dynamics* 177 (1987).

9. H. Myong and T. Kobayashi, "Numerical simulation of developing flows in square duct with an anisotropic k-e turbulence model," *Seiken Kenkyu* 42(1) (1990).

10. F. Gessner and A. Emery, *Journal of Fluids Engineering* 103 (1981).

11. K. Horiuti, "Anisotropic representation of the Reynolds stress in large eddy simulation of turbulent hannel flow," *Proceedings ISCFD Nagoya* (1989).

12. Y. Miyake and T. Kajishima, "A discussion on turbulent flow in channels on the basis of large scale LES," *Proceedings ISCFD Nagoya* (1989).

13. K. Horiuti, "The role of the Bardina model in large eddy simulation of turbulent channel flow," *Physics of Fluids A* 1(2) (1989).

14. A. Yoshizawa, "Statistical theory for compressible turbulent shear flows with the application to subgrid modeling," *Physics of Fluids* 29 (1986).

15. N. Mansour, J. Kim, and P. Moin, "Reynolds stress and dissipation rate budgets in a turbulent channel flow," *Journal of Fluid Dynamics* 194 (1988).

16. Y. Takakura, S. Ogawa, and T. Ishiguro, "Turbulence models for 3D transonic viscous flows," *Proceedings ISCFD Nagoya* (1989).

17. K. Sawada, "Aerodynamic analysis of a reentry vehicle," *Proceedings of the 26th Aircraft Symposium Sendai* (1989).

18. Y. Yamamoto, N. Suzuki, and K. Mori, "Numerical simulation of hypersonic viscous flow for the design of Japanese H-II orbiting plane HOPE," *Proceedings ISCFD Nagoya* (1989).

19. T. Tamura, K. Tsuboi, and K. Kuwahara, "Numerical simulation of unsteady flow patterns around a vibrating cylinder," AIAA Paper 88-0128 (1988).

RECENT JAPANESE RESEARCH ON OCEAN WAVE-STRUCTURE INTERACTIONS

Henry T. Wang

Japanese research on ocean waves and their interactions with offshore structures ranges over a broad spectrum of activities and applications. Many of the research activities aim at introducing new techniques for wave measurement, generation, and modification. Recent research efforts on ocean wave-structure interactions were surveyed during site visits to 11 Japanese marine engineering research institutes.

INTRODUCTION

During the last 2 weeks of September 1989, both before and after the Fifth International Conference on Numerical Ship Hydrodynamics held in Hiroshima, I made a series of visits to Japanese marine engineering research institutes to survey the latest research activities on ocean waves and their interactions with offshore structures. This is, of course, one of the major research areas for this island nation, which is the world's leading shipbuilder and much of whose land is located within 60 miles of a seashore. In all, I made a total of 10 on-site visits and one off-site visit, listed below in the order that they were made:

1. Institute of Industrial Science (IIS), Tokyo University, Roppongi Campus. Host: Prof. T. Kinoshita.

2. Dept. of Naval Architecture, Tokyo University (TNU), Hongo Campus. Hosts: Profs. H. Kajitani and H. Kato.

3. Dept. of Naval Architecture and Ocean Engineering, Yokohama National University (YNU). Host: Prof. T. Hirayama.

4. Ishikawajima-Harima Heavy Industries Co., Ltd. Research Institute (IHI), Yokohama. Hosts: Drs. S. Yamashita and S. Ogiwara.

5. Ship Research Institute (SRI), Ministry of Transport, Mitaka (near Tokyo). Host: Mr. S. Kato.

6. Akishima Laboratory, Mitsui Engineering & Shipbuilding Co., Ltd. (MES), Akishima (near Tokyo). Hosts: Drs. K. Shimada and M. Kobayashi.

7. Dept. of Naval Architecture and Ocean Engineering, Osaka University (ONU), Suita (near Osaka). Host: Prof. K. Saito.

8. Dept. of Naval Architecture, Osaka Prefecture University (OPU), Sakai (near Osaka). Hosts: Profs. Y. Ikeda and Y. Himeno.

9. Akashi Ship Model Basin Co., Ltd. (ASMB), Akashi (near Osaka) (off-site visit). Host: Dr. M. Takagi.

10. Tsuyazaki Sea Safety Research Laboratory, Research Institute for Applied Mechanics (RIAM), Kyushu University, Tsuyazaki (40 miles north of Fukuoka). Host: Prof. K. Kawatate.

11. Dept. of Naval Architecture and Ocean Engineering, Hiroshima University (HIU), Higashi-Hiroshima (20 miles east of Hiroshima). Host: Prof. M. Takaki.

The above institutes include national universities (TNU, YNU, ONU), research centers affiliated with universities (IIS, RIAM), locally supported universities (OPU, HIU), industrial research laboratories (IHI, MES, ASMB), and a government laboratory (SRI). It is not by coincidence that all of the above sites lie close to stops on the high speed Shinkansen east-west rail line connecting Tokyo to Fukuoka. This is the country's single most important transportation line. In the large majority of cases, the visit consisted of a guided tour of the wavemaking and other experimental facilities, technical discussions with the host and other researchers of the laboratory, and the transmittal of reports and papers describing their recent research. At my request, in order to obtain information on the most recent research, a number of the documents were in Japanese. Typically, research results are first published in Japanese and, after a number of refinements, later appear in English language versions.

BRIEF DESCRIPTION OF INSTITUTES

I will not attempt here to give a detailed description of the administrative, organizational, or physical features of each institute. Instead, I will concentrate on some general institutional features which differ significantly from American practice. I will also mention noteworthy features or recent developments of interest for particular institutes.

In the case of the universities, it is of interest to note that the school year runs from early April to the end of February instead of from September to May. The position of department chairman is apparently rotated on a yearly basis among the senior faculty members. Several of them lamented the fact that many of the B.S. and even M.S. graduates entered fields not related to ocean engineering, such as banking and insurance. The dominant reason seems to be substantially higher pay. It is not often that American students will go through a rigorous engineering curriculum and then seek other employment. Also, Japanese students do not contact the companies directly, but instead make their wishes known to the department chairman, who then "introduces" them to appropriate employers.

The organizational structure varies from university to university. The senior faculty members at the institutes associated with Tokyo University, IIS and TNU, enjoy a degree of autonomy not apparent elsewhere. Each senior member heads a "laboratory" consisting of several research assistants and graduate students. At OPU, the department is divided into four chairs, each headed by a full professor. At RIAM, the institute is divided into groups, each with one full professor, one associate professor, and several research associates or graduate

students. The organization at the remaining universities seems to be less structured and close to that at American schools. The naval architecture department at YNU offers a special program, in which all the courses are given in English, to foreign students pursuing doctoral degrees.

As for physical location, Prof. Kinoshita pointed out that the Roppongi district, where IIS is located, is the most expensive area in Tokyo and hence in all of Japan. As a result, there are only two very small experimental channels located in the basement of his building. The institute does own the experimental facility at Chiba City, located some 25 miles to the east, across the Tokyo Bay. Among the facilities there is a large seakeeping and maneuvering basin with capability for waves, wind, and current. In 1982, the Faculty of Engineering of HIU moved to the new Saijo Campus in Higashi-Hiroshima as the first of a series of moves to have a unified campus at this new location. RIAM is located in a beautiful and serene ocean resort area at the northeastern corner of Kyushu Island.

The three industrial research centers, IHI, MES, and ASMB, represent different ways of affiliation with the parent company. IHI has a direct affiliation, MES is financially autonomous, while ASMB represents a joint investment by Kawasaki Heavy Industries, Ltd. and Hitachi Zosen Corporation (HZC). The IHI research center has on-site dormitory facilities for visiting officials from other branches of the company. As a sign of the high premium on land in this country, some of the buildings near the entrance of this center must unfortunately be razed (and relocated inside the complex) to make way for a highway. Dr. K. Shimada of the MES research center pointed out that as a result of its financial autonomy, the amount of basic research work has decreased.

The government laboratory, SRI, is composed of nine technical divisions engaged in research on ship propulsion and dynamics, structural mechanics and materials science, power, low temperature environments, and nuclear technology. This scope of work is carried out by a staff of approximately 265. By way of contrast, a similar American laboratory would have a staff several times larger.

EXPERIMENTAL WAVEMAKING FACILITIES

The waves are generated in a variety of facilities including towing basins, wave tanks, water channels, and maneuvering basins. The first three types are characterized by length-to-width ratios of the order of ten, while the last type is more squarish with values of the ratio between one and three. In most cases, the principal wavemaking mechanisms are installed in the towing basins. Listed below, in order of increasing length, are the length, width, and depth dimensions in meters of the largest towing basin at each institute:

1. OPU: 70 x 3 x 1.6
2. RIAM: 80 x 8 x 3
3. HIU: 80 x 8 x 3.5
4. TNU: 86 x 3.5 x 2.4
5. ONU: 100 x 7.8 x 4.4
6. YNU: 100 x 8 x 3.5
7. ASMB: 200 x 13 x 6.5
8. IHI: 210 x 10 x 5
9. MES: 220 x 14 x 6.5
10. SRI: 400 x 18 x 8

It can be seen that the basin sizes fall into three groups: those at the universities are of the order of 100 m, the industrial basins are approximately twice as long, while the government laboratory has the longest basin. In all of these basins there is the

capability of generating unidirectional (or long-crested) waves propagating along the length of the basin composed of one frequency (regular waves) or a series of frequencies (irregular waves). These waves are generated by a single unit plunger or flap moving with prescribed motions. In some of these basins (RIAM, YNU, ASMB, and a smaller 100- x 5- x 2.7-m MES basin), the wavemaker consists of a series of snake type plungers that may move independently, resulting in the generation of multidirectional (or short-crested) waves. Until recently, these waves have not been attempted in towing basins since it was felt that the two sidewalls would limit the range of possible wave directions. The newest wavemaker of the short-crested type is the one at YNU, and it is composed of 16 independent units. S. Takezawa and T. Hirayama of YNU have made detailed studies of the behavior of the generated waves in a basin. The main drawbacks are that the feasible wave directions are limited to ±45° measured from the principal direction, which in turn is now constrained to be along the basin length. The principal advantage is that the generated random wave field is statistically uniform along most of the basin.

On-site maneuvering and seakeeping basins are available at TNU, IHI, and SRI with respective length and width dimensions of 80 x 30 m, 70 x 30 m, and 80 x 80 m. In these facilities, irregular long-crested waves may be generated in two perpendicular directions. The unusually large size of the SRI basin is due to the fact that it is an outdoor pond. M. Kan of SRI showed films of capsizing tests of a remotely controlled ship model traveling prescribed courses in the presence of the generated waves. This project is being done in cooperation with the Federal Republic of Germany.

WAVE MEASUREMENT, MODELING, AND MODIFICATION

One of this country's principal interests in the utilization of ocean space is the use of offshore platforms to serve such diverse purposes as factories, storage areas, seaports, or airports. Thus, under the leadership of S. Ando, the director of the Ocean Engineering Division, SRI, in collaboration with a number of industrial companies, is conducting a major at-sea experiment involving the floating platform POSEIDON. This structure is 34 m long, 24 m wide, 26 m high, submerged 5.5 m, and has a displacement of 531 tons. It has 12 columns arranged in three rows and is moored by six slack chains approximately 2 miles north of Yura Port in the Japan Sea. The experiment began in September 1986. This platform is meant to serve as the prototype of an actual platform that may be three times larger. The platform gathers a variety of data including the ocean environment, its own motions, cable tensions, and structural strains. In addition, corrosion behavior of the 12 columns is observed, where 1 column is made of concrete and the remaining 11 are made of steel with different paints on the surface. The platform is unmanned, with personnel periodically going onboard to collect the recorded data.

The data are recorded in two modes. The regular mode is to record data for 34 minutes at intervals of 0.5 second every 6 hours. There is also the option of manually starting the recording to collect data during severe sea conditions. The data on ocean waves are obtained by twice integrating measured vertical accelerations as well as by ultrasonic waveheight meters mounted on the sea floor, which is at a depth of 180 m. The data from both methods are in good agreement. The data indicate that the

measured energy spectrum is rather sharply peaked and is in better agreement with JONSWAP (Joint North Sea Wave Project) than with that proposed by ISSC (International Ship Structure Congress). Also, it is found that the commonly used value of 3.3 for γ, the enhancement factor near the peak region, is correct only for a fully developed sea. The data are also analyzed to give information on wave grouping, directional distribution of the wave energy, and correlation between wave height and period.

On a smaller scale, from the idyllic seashore town of Tsuyazaki, K. Kawatate of RIAM routinely carries out at-sea measurements of surface as well as subsurface environmental data in the waters surrounding Kyushu Island. First, there is a research tower located 1.2 miles offshore that can be conveniently reached by a small boat. A larger boat is available to deploy or retrieve data gathering moorings, which are located further offshore. His day-to-day concerns include frequent communication with the local fishermen to avoid deploying moorings in heavily fished areas, cut lines due to human activity or shark bites, and enlisting the aid of the local authorities in locating lost moorings. Along with H. Hongi and A. Kaneko, he has developed a self-governing profiling system that consists of a self-powered moving sensor unit whose vertical motions are controlled by a microprocessor. He calculates the dynamic motions of his moorings by using a method that considers only the angular (or transverse) motions of the cable system, thus bypassing the in-line (or longitudinal) motions, which usually dominate computer time requirements. Using this approach, he reports a reversal in the usual computer time behavior, i.e., the calculation time for nylon rope treated as being inextensible is only one-sixth of the extensible case.

T. Hirayama of YNU is investigating the possibility of obtaining real-time estimates of sea spectra based on the measured dynamic motions of the ship itself. He feels that onboard wave recorders are affected by the motions of the ship, overboard buoys are relatively difficult to use, and visual observations are subjective and difficult to conduct at night. He uses Fast Fourier Transforms (FFT) to obtain the ship motion energy spectrum from the measured ship motions. He then gets the sea wave spectrum by dividing the motion spectrum by the square of precalculated motion transfer functions, which are stored in the onboard microcomputer. The transfer functions are calculated by using the so-called "New Strip Method," which better accounts for hydrodynamic interaction between ship sections than traditional Strip Theory. He reports that, on the whole, there is reasonable agreement of his calculated spectra with those obtained by direct wave measurements using an onboard Tucker type recorder and an overboard buoy.

M. Takagi of ASMB and HZC is concerned with the mean water level of the waves generated by the wavemaker in a towing basin. By using second-order theory, he shows that for the case when the wavemaker is generating two wave components of different frequencies, the mean water level is composed of two terms: a constant $-\alpha_1$, which always results in a lowering or "set-down" of the water level, and a slowly varying long-wave sinusoidal term of amplitude α_2. Thus, for those cases where $\alpha_2 > \alpha_1$, there locally may be a raising or "set-up" of the water level. Thus, the traditional term "set-down" should really be changed to "group-induced long-wave."

Traditionally, passive beach-type dampers have been used to absorb the waves at the ends of a wave basin. More recently,

active absorbers are being considered. For the case of an incident wave with a single frequency, a spring-dashpot-floating body system, with natural frequency equal to the frequency of the wave and damping coefficient equal to the damping of the waves radiated by the body, is a highly efficient wave absorber. S. Naito and S. Nakamura of ONU treat the case of irregular waves composed of many frequencies. Here, it is necessary to satisfy the equivalent of the single-frequency conditions in the time domain. The basic idea is to continuously measure the elevation of the incoming wave at a point in front of the body, extrapolate this elevation to the actual location of the wave absorbing body, and calculate a convolution integral, which gives the required control force that leads to motions of the body, which give rise to maximum energy absorption. Unlike the single-frequency case, complete absorption is usually not possible.

T. Kinoshita of IIS considers a number of devices to modify the incoming ocean waves, to either mitigate their harmful effects or utilize their beneficial effects. In the case of mitigation, breakwaters often are needed to minimize the wave effect on harbors and offshore structures. Usually, these breakwaters are set with their lengths perpendicular to the incident waves to maximize the reflected (and hence minimize the transmitted) waves. Unfortunately, this often places large loads on the mooring lines anchoring the breakwater. He experimentally shows that by using a "multi-body-type" of floating breakwater, whereby A-shaped flat plates are placed parallel to the incoming waves, much smaller forces are experienced by the mooring lines to obtain transmission coefficients equivalent to those for the conventional type. As a result of the lower forces, he estimates that the weight of the mooring lines is reduced by a factor of 15 compared to that needed for the conventional type. He also considers hypothetical bodies, as represented by specified singularity distributions, which give no reflected waves upstream and "focus" the incoming single-frequency wave at the downstream point $x=L$, $y=0$ where L may be considered to be the focal length. Typically, wave amplitudes at the focal point are five times larger than that of the incoming wave. One possible application is for recreational purposes.

Along with H. Maeda and K. Masuda, T. Kinoshita also investigates the design of devices to extract useful energy from the ocean waves. They estimate that perfect conversion of the wave power along the 3,000-mile coastline of Japan would supply about one-half of its electric power needs. There are presently no wave energy extraction devices in full-scale operation. The essential idea is to design devices that minimize the transmitted and reflected wave field, thus maximizing the energy that is extracted. Three types are currently under world-wide consideration: the Salter Duck, the Articulated Raft, and the Oscillating Water Column (OWC). The first device gives the desired wave field through design of body shape, the second device achieves the result by means of body deformation, while the last device concentrates on maximizing the efficiency of the energy conversion process. The authors consider in detail the OWC type where the ocean wave is trapped in a column and its energy is transmitted by an air column to a turbine. The authors report total efficiencies of the order of 10 to 20 percent.

LINEARIZED ANALYSES OF WAVE-STRUCTURE INTERACTIONS

The increased computing speed and memory capabilities of modern mainframe computers, novel uses of offshore structures,

and the desire to minimize needless over-design have led to increasing use of the nonlinear analysis approaches described in the following section. Nevertheless, linearized analyses continue to be widely used due to their relative simplicity of calculation, ease of interpretation, as well as generality of application of the calculated results. For example, most of the investigations discussed in the preceding section make explicit use of linearized techniques or assumptions. These analyses are usually carried out in the frequency domain.

The basic building block of most linearized analyses is the Green function, which represents a singularity that satisfies all the boundary conditions of the problem (including the troublesome free surface condition) except for the kinematic condition of no flow through the structure surface, which then serves to determine the strengths of the singularities distributed on this surface. The three most widely used Green functions are the zero speed case for a pulsating stationary source, the wave resistance case for a non-pulsating translating source, and the general radiation case for a pulsating translating source. The current status is that robust and efficient computation methods exist for the zero speed case, and tractable (though not necessarily both efficient and robust) schemes have recently been developed for the wave resistance case. Thus, the current major effort is on developing computation methods for the radiation case.

At MES, M. Kobayashi and K. Shimada have incorporated in their structural dynamic response program "DREAMS" a calculation method that makes a direct evaluation of the usual double integral representation of this function. A series of transformations is performed to convert the complex integrals to a more tractable real form.

H. Iwashita and M. Ohkusu of RIAM start instead from a unique single integral representation of the function and evaluate the resulting integral along numerically calculated paths of steepest descent on which the oscillatory behavior of the integrand is minimized. They report that accurate evaluations (for given values of the frequency, and locations of the source and field points) only require computer times of the order of 0.01 second on a FACOM M 780/20 mainframe computer. Their work offers the hope that problems involving oscillating structures with forward speed or in the presence of a current may be solved satisfactorily in the near future. In fact, Y. Higo and K. Sato of HIU use a preliminary version of this method to calculate the added resistance of a surface piercing cylinder advancing in waves.

S. Yamashita of IHI analyzes the behavior of a variety of structures with protruding underwater shapes. It has been well known for some time that by placing a suitable bulbous bow at a certain distance below the free surface, the resulting body experiences no exciting forces in the vertical (heave) direction at a certain frequency. While experimental measurements do confirm the existence of this "wave-free" frequency, the region is sharply tuned; that is, the exciting forces increase rapidly on either side of this frequency. By changing the shape of the underwater bulb and moving it further below the free surface, he shows that the resulting body has two wave-free frequencies for the heave forces. In addition, these forces are now relatively small for all frequencies larger than the lowest wave-free frequency. More recently, he extends this idea to obtain totally submerged and floating bodies that are wave-free in the sway direction, which is the horizontal direction perpendicular to the incident wave. The basic approach is to trace

the streamlines of velocity potentials that satisfy the wave-free condition of no radiating waves when the body oscillates in sway. The floating body cases are characterized by a sharp narrowing of the cross section as the free surface is approached. Experimental measurements of the sway force tend to have a minimum at the calculated wave-free point but do not go completely to zero. As an example of the ease and generality of application of the results obtained from linearized analyses, he gives a series of charts showing the wave frequencies, as functions of semi-submersible parameters, at which the heave response is large. These widely used structures are characterized by an above water deck supported by vertical columns that terminate in underwater pontoons.

In linearized analyses, the amplitudes of both the exciting waves and body motions are assumed to be small. As an example of the relaxation of the requirement for small body motions while still retaining the simplicity of the frequency domain analysis, S. Yamashita calculates up to third order (or harmonic of the basic frequency) the forces on a thin body heaving with large amplitude. The time variation of the body wetted surface as a function of heaving amplitude is now considered in calculating the exciting forces. As may be expected, the agreement between calculated and measured forces is excellent for first order, reasonable for second order, and only fair for third order.

NONLINEAR ANALYSES OF WAVE-STRUCTURE INTERACTIONS

Nonlinear analyses are needed when the motion or wave amplitudes are large or nonlinear forces such as the viscous drag are significant. These analyses are usually carried out in the time domain. Since the added mass and wave damping coefficients are not constants but functions of the frequency of motion, the equations take the form of integro-differential equations. The integral involves a convolution integration from the initial time t=0 to the present time t of the product of the memory (or impulse response) function and the body motion. K. Saito of ONU and M. Takagi of ASMB and HZC have made detailed investigations of the analytic evaluation of this function, its determination from experimental tests, and methods of solving the integro-differential equations of motion. In the case of analytic evaluation, the memory function is essentially the Fourier transform over all frequencies of the wave damping coefficient. To facilitate this evaluation, they derive asymptotic formulas for this coefficient at high frequencies. In the case of solution of the equations of motion, they find that the use of the convolution integral gives calculated motions that are consistently in good agreement with measured results for the case of a body moored by cables with various load-deflection curves. When an attempt is made to simplify the equations by assigning constant values to the added mass and damping coefficients corresponding to either the natural frequency of the system ω_n or the peak frequency of the exciting waves ω_p (thus avoiding the need to evaluate the troublesome convolution integral), the results are usually poor for the ω_p case. They are reasonable for the ω_n case when the mooring nonlinearities are relatively weak, i.e., when the system is not subject to sudden impulse-type loads such as those that occur when a slack rope suddenly becomes taut.

A number of choices are available for the experimental determination of the memory function. The tests may be conducted as forced or free oscillations of the body, the integral may be evaluated in the

time or frequency domain, and the integral may be evaluated directly or in correlation form (Blackman-Tukey method). After systematically carrying out the above approaches, they conclude that the Blackman-Tukey method gives the most consistently accurate estimates of the memory function in both the frequency and time domains.

Y. Higo and M. Takaki of HIU consider the forces acting on two-dimensional and axisymmetric bodies undergoing large heave motions. Their work may be considered to be the time domain equivalent of S. Yamashita's frequency domain approach. In this case, the memory function must be updated for a new underwater shape at each instant of time. Their approach is as follows. The flow field around the body is divided into two parts: a wave field caused by the body motions during the previous time steps (thus accounting for the past motions) and an impulsive (infinite frequency) motion of the instantaneous underwater body. The wave field and underwater body shape then are updated before proceeding to the next time step. As in the case for S. Yamashita, the agreement of their calculated results with experimental values is good for first order and progressively worsens with increasing order.

In most of the preceding analyses, potential flow methods have been used in that the effect of viscosity has been either completely neglected or simply accounted by adding a term for the viscous drag force, which is a nonlinear function of the fluid velocity relative to the body. This is usually permissible for floating bodies near the free surface since the wave damping is larger than the viscous drag. However, for cases where substantial parts of the body are located below the free surface, for certain body shapes, or modes of motion, the effect of viscosity can no longer be neglected. In these cases, there is a complex interaction between the viscous and potential flow components. Thus, the viscosity-induced shedding of vortices changes the pressure distribution and thus the added mass coefficients computed from potential flow. Similarly, the unsteady flow due to the ocean waves affects the development of the boundary layer and vortex generation and thus the viscous drag on the body. A key dimensionless parameter governing the extent of this interaction is the well known Keulegan-Carpenter (KC) number, which may be viewed as the ratio of the diameter of the wave particle orbit to a representative body length. The effect of viscosity increases with increasing KC number. Y. Ikeda, K. Otsuka, and N. Tanaka of ONU experimentally and analytically investigate the effect of KC number on the added mass and drag coefficients of horizontally placed cylinders in the presence of regular and irregular waves. Experimentally, they find that at the relatively low KC number of 2, the measured added mass coefficients are only one-*half* of the potential flow values. The KC number has less of an effect on the drag coefficient. These results are qualitatively confirmed by their theoretical model, which uses discrete vortices. The vortices are placed such that the circular cylinder shape is obtained by using the well-known potential flow "circle theorem" and the free surface is approximated as a rigid wall by simple reflection of the underwater vortices. The location and strength of the shed vortices are based on a simple model for the development of an oscillating boundary layer. This model is very useful for observing the effect of previously shed vortices or "memory effect" on the development of flow around the cylinder.

The principal focus of the hydrodynamic analysis of floating platforms such as the POSEIDON is on a specific and seemingly unimportant aspect: the surge and sway motions (the horizontal directions, respectively, parallel and perpendicular to the incident waves) at very low frequencies that are below the frequency range for the principal energy content of the incoming waves. Thus, the forces here arise due to nonlinear interactions and hence are small to higher order. The problem arises because of the low natural frequency of the moored platform due to the lack of a hydrodynamic restoring force in the horizontal directions and the low restoring force of the slack cables mooring the platform. This fact, coupled with low damping for these modes of motion, may lead to large second-order, low-frequency resonance type of motions. As a result, the structure and mooring cables must be carefully designed to avoid this phenomenon. This means that the force coefficients must be carefully determined, not only as a function of wave frequency but also of wave amplitude, i.e., of KC number. The nonlinearity of the response to the exciting random waves also makes more difficult the extrapolation of calculated or measured model motions (usually of the order of minutes of real time) to extreme values of the response over a span of hours or perhaps days, the typical duration of a storm. The combination of the usefulness and industrial need for these platforms and the complexity of the analysis of the low-frequency horizontal motions has made this an area of active world-wide research for the past 20 years.

S. Kato and S. Ando of SRI and T. Kinoshita, S. Takase, and K. Takaiwa of IIS are actively engaged in research in this area with, of course, specific application to the POSEIDON. There are basically two steps that are required to obtain the extreme response statistics to expected ocean storm waves. First, the short-term response behavior may be obtained in one of two ways. One is to painstakingly conduct forced oscillation tests to measure the force coefficients as a function of wave frequency and amplitude, and motion frequency and amplitude, and then use them to solve the integro-differential equations of motion to obtain the response behavior in various sea states. The second alternative is to directly measure, in a model basin, the platform response to these sea states. When the response is linear, the extrapolation to obtain extreme responses over longer times is relatively straightforward. In fact, the calculation procedure is very similar to that used for the exciting waves themselves. When the response is nonlinear, this is no longer the case and the calculation procedure is considerably more complex. Now, both the first (linear) and second order (quadratic) response spectra must be obtained from the measured or calculated responses. The resulting estimate of the extreme responses is not precise and involves a number of approximations concerning the interactions between the motions, the bandwidth of the response, and finite series representations of the probability density functions. The present researchers show that inclusion of the statistical interference between the first and second order responses leads to extreme values that are typically 10 percent higher than those obtained by neglecting this interaction.

CONCLUDING REMARKS

Japanese research on ocean waves and their interactions with offshore structures ranges over a broad spectrum of activities and applications. The POSEIDON

floating platform and Oscillating Water Column wave energy absorption projects offer the possibility of better future utilization of the offshore waters as resources for expanded working space and additional electric energy, both of which are in short supply in this country. Many of the research activities aim at introducing new techniques for wave measurement, generation, and modification. These include the measurement of the motions of the ship itself to obtain real time estimates of the ambient sea waves, the use of active devices to dampen waves, the generation of short-crested waves in a long towing basin, and the use of breakwaters aligned parallel to the incoming waves. While the use of the more accurate time domain nonlinear analyses is, of course, increasing, traditional linearized analyses in the frequency domain continue to be widely used due to their simplicity of calculation and ease of interpretation. Here, the recent development of a promising method for the calculation of the radiation Green function for a translating pulsating source offers the hope of more accurate analyses for offshore structures moving with forward speed or in the presence of a current. In the case of the more difficult and complex nonlinear analyses, research activities are proceeding along a number of directions. One approach is to develop more efficient analytical and numerical evaluations of the memory or impulse response function as well as to identify the optimum experimental techniques for obtaining this function. Another approach is to conduct experimental and simplified analytical calculations on standard bodies such as circular cylinders to obtain better physical understanding of the complex interactions between the wave field, body motions, and vortex generation at the body surface. For more complex actual structures such as the POSEIDON, the approach is to painstakingly measure the force coefficients over a matrix of wave and motion frequencies and amplitudes and obtain the motion response in the time domain by solving integro-differential equations of motion. Or, the motions may be directly measured in model tests for different expected sea states. Finally, the techniques of probability theory for nonlinear responses are being refined to obtain better estimates of expected extreme responses in storms, based on extrapolation of the above calculated or measured short-term motions.

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THE PAX COMPUTER AND QCDPAX: HISTORY, STATUS, AND EVALUATION

David K. Kahaner

The PAX parallel processing project developed at the University of Tsukuba by T. Hoshino is summarized. PAX is a two-dimensional array of processors that operate in MIMD form. QCDPAX has a fast floating point unit specially programmed for QCD calculations. Peak performance is 14 GFLOPS.

INTRODUCTION

Modern computing for the solution of scientific and engineering problems began in the 1940s. It was recognized by Von Neumann and others that simulation or modelling of real world phenomena could be used to reduce the amount of physical experimentation in certain situations. When no experimentation was possible it was hoped that models would allow extrapolation and prediction of new results. Weather modelling provides an excellent example. Solving the differential equations describing the temporal evolution of pressure, temperature, and associated variables was one of the earliest motivations for computer modelling. Even today the problem is largely unsolved although tremendous progress has been made. This growing desire to compute has fueled research in computers and computational science. There are many papers detailing the need for ever faster hardware and software. While some of the original problems can now be solved, science's appetite for computing has grown at least as rapidly as the technology has been able to provide solutions. There is no reason to think that this trend will abate.

Computers were originally sequential, each operation occurring in its own turn. This is essentially the "Von Neumann model," although early scientists appreciated that there is often simultaneity in nature that could be exploited. A substantial amount of simultaneous processing takes place in all computers today. For example, input and output are performed asynchronously with arithmetic processing. But it is only within the last 10 to 15 years that parallel or nonsequential numerical processing has been available.

Here, some aspects of a long-term parallel processing research project (PACS, PAX, and QCDPAX) begun in 1977 at Kyoto University and Hitachi Corporation's nuclear power division are summarized. The initial name, Processor Array for Continuum Simulation (PACS), was soon changed to Processor Array eXperiment (PAX). QCDPAX is the current running computer (see below). Unless it is necessary to distinguish between them, we refer to the family as PAX computers. Research is now centered at the Institutes of Engineering Mechanics and Information Sciences, University of Tsukuba, Ibaraki 305 Japan. The principal investigator is Professor Tsutomu

Hoshino, although he has many long-term collaborators, including Professors Shirakawa, Iwasaki, Oyanagi, and others.

A number of papers (Ref 1-9) detailing this work are listed in the references. This report is the result of analyzing many of these, several visits between December 1989 and January 1990 to Professor Hoshino's Tsukuba laboratory, and an examination of some programs that are now running on QCDPAX.

The PAX idea was to capitalize on the obvious parallelism in many continuum problems, the rapidly decreasing costs of computer hardware, along with its associated miniaturization. These ideas have been pursued by other researchers, and PAX was in many ways inspired by research on the ILLIAC IV. The latter was a SIMD computer (single instruction, multiple data) in which a control unit forced a large number of identical processors to perform identical calculations on different data. ILLIAC IV was seminal for the subsequent development of parallel computers, but it was never commercialized. Even today it is extremely difficult to design a SIMD computer that can cope with data dependent branching, and this has restricted SIMD's applicability to special kinds of problems such as image processing. Current SIMD machines, for example the ICL DAP, are often criticized for this restriction.

PAX also uses several hundred identical processors, but each of these can operate independently. This is usually referred to as MIMD processing--multiple instruction, multiple data--although the idea was known before PAX. Supercomputers such as the Cray Y/MP or NEC SX-3 utilize very powerful asynchronous processors, but typically fewer than 16. Careful programming can sometimes lead to speedups nearly equal to the number of processors. Synchronous or asynchronous multiprocessing, sometimes called spatial replication (Ref 2), is today's best bet for substantial performance improvements and is a major part of current research in high performance computing. However, very few scientific computations can be performed completely asynchronously. That is generally limited to searches of tables for state variables, calculation of material properties, portions of ray tracing algorithms, etc. that are data driven and hence will be different for each process. Thus a program may need to determine information about a function at a large number of points on the boundary of a region before further processing. Each of these computations may be done asynchronously, but it will also be necessary to globally synchronize before proceeding from these results. Similarly in any computation involving iteration or time integration, a global synchronization of all parallel tasks must be performed. However, between these points the calculations are independent and may be performed asynchronously. Thus a good model for real problems is "quasi MIMD" (Ref 3).

Supercomputers also incorporate "pipelining" within their arithmetic units. This means that an operation such as multiply is broken down into a number of steps, where each can proceed concurrently on distinct operands. This provides a different type of parallelism and has successfully generated performance improvements of perhaps one order of magnitude, roughly equal to the number of sections or steps in arithmetic operations. Pipeline computers are often referred to as "vector" computers. Sometimes two or more operations, such as + and *, can be "chained" together to provide further speedup. If there are independent arithmetic units several operations can be done simultaneously. Breaking arithmetic operations into sections requires some additional hardware and results in its own increased overhead; it is necessary to "latch"

between sections to synchronize. New hardware devices such as Josephson junctions might provide a means of increasing the number of steps without introducing too much additional latching overhead. There is also the possibility of pipelining from memory so that operands can be provided to the arithmetic units in greater number per unit time. Currently this is not being done, although the primary restriction seems to be economic. Pipelining is an essential ingredient in improving computer performance, but additional gains to be obtained from it appear to be limited. Most computer scientists think of spatial replication as true parallel processing and feel that it has the most potential for high performance.

PAX

The Introduction above provides a setting for describing the work by Hoshino and collaborators. The physical questions that originally motivated Hoshino were related to nuclear reactor models, and from these he became interested in "action through a medium" problems. For example, fluid flow equations are normally derived by describing various conservation laws on a small volume of material. Thus the state at point P is mostly determined by local data around P. Similarly, in statics problems, such as solving the Laplace or Poisson equation, the usual approach is to discretize the region and compute approximations to the spatial derivatives at P by suitable averages of data adjacent to P. Finite differences in two dimensions take five-point or nine-point averages; finite element approximations can be described in the same way. On the other hand many particle problems do not satisfy this proximity condition, nor do many important numerical methods, such as Gaussian elimination with partial pivoting.

All PAX computers have shared the same basic design philosophy:

- A high performance parallel computer to solve specific real engineering problems rather than general problems.
- Multiple processing units (PU) arranged in a torus or two-dimensional rectangular lattice (nearest neighbor mesh, NNM).
- Fast connections for data between neighboring PUs.
- Synchronization and broadcasting between many, or all, PUs whenever necessary, but otherwise independent MIMD processing.

Various PAX computers have been constructed; they are named according to the number of PUs: PAX-9, PAX-32, PAX-128, QCDPAX-240, and QCDPAX-488. The major differences between them are the number of processors, the specific hardware technology used in each PU, the connection network, the memory and, in the case of the last two, the application software that is being developed. QCDPAX-488 is still under construction as this is written. It is scheduled for completion in March 1990 and will have a peak performance of about 14 GFLOPS.

Hardware

The PAX computer system consists of an array of PUs, a host computer, and an interface unit (HPI) to communicate between the host and the PUs. In QCDPAX each PU contains a Motorola MC68020 (CPU) with a clock speed of 25 MHz. The host is a Sun 3-260 workstation with a color graphics display. In QCDPAX-488 the PUs are arranged

in a 24 by 16 array; QCDPAX-288 has them arranged in a 24 by 12 array. The PUs are arranged toroidally. By that we mean that the eastern end of each row is also adjacent to the western end, similarly for north and south.

One particularly interesting design feature of all PAX computers is the provision for fast floating point computation. This is an integral part of most scientific computing but is not always included in multiprocessing computers of a size comparable to PAX. For example, the ICL DAP lacks hardware for floating point. (All supercomputers provide floating point hardware.)

In QCDPAX each PU contains a vector processing unit (VPU) with floating point hardware, memory, and control circuits. For fast floating point computation Hoshino and his associates decided that the usual floating point processor, Motorola 68881, that is often provided with 68020 chips was not fast enough. Instead, they selected as a floating point processor (FPU) the LSI L64133 that has a peak arithmetic performance of 33 MFLOPS. This chip can perform both a 32-bit floating point add and multiply in a single clock period. They have incorporated the L64133 into the VPU, which also has 2 MB of high speed (25-ns) SRAM for data memory (dm), another 8 KB of similar memory called writable control storage (wcs) for the microcode (software) to support the floating point operations, and 1 KB ROM for a look-up table. There is a three-part pipeline associated with instruction fetch-decode-execute. This pipeline, along with the two simultaneous arithmetic operations, accounts for the name "vector processor." Floating point operations occur after the CPU sends instructions and data information to the VPU, which then operates independently. Computations such as evaluation of the elementary functions, random numbers, and some matrix computations have been programmed via microcode into the wcs. There are no wait states when the CPU addresses the wcs. The VPU also supports vector operations that are set up by the CPU but run by the wcs and the FPU. Compared to the 68881, the FPU is difficult to program and programming problems have been a significant time sink for the small PAX research group. Nevertheless, it accounts for the high peak performance of QCDPAX.

Communication and Memory

In addition to the 68020 CPU and VPU, each PU contains communication hardware and several different kinds of memory. The PU communicates rapidly to four PUs on the east, west, north, and south by communication memories (cm). Each of these is an 8-KB two-port RAM and thus can be accessed by the PUs that share it. Adjacent PUs thus communicate by reading and writing into the same memory location. Synchronization is by a flag register. The PUs also communicate rapidly with the host by another 8-KB two-port RAM that is associated with the HPI and is mapped onto the address space of the host. As the host writes to its memory it also sets a switch indicating which PU is to get the data, and that data item then becomes available at the appropriate PU. Communication between a PU and the host works in the same way. Also, by overlapping the addresses, i.e., having all the PUs associated with the same memory locations on the host, the latter can transmit identical data to all the PUs. This mechanism also transmits data from one PU to all the others. In PAX descriptions this type of communication is known as a "ferry." Each PU also has 4 MB of DRAM local memory (lm); this is used to store the PU program and whatever local data it requires.

Host

The host computer is used to compile and assemble source programs, load them into the array of PUs, initiate parallel tasks, send and receive data from the PUs, and output the results to a user via files and the color display. Each local PU, or node, runs whatever program is loaded into it. All PUs are normally loaded with the same program, but this is not a requirement. (This is similar to other asynchronous multiprocessors having many PUs.) Different data at each node means that the program execution path, or thread, is likely to be different for each PU.

Parallelism

To summarize, PAX has four levels of parallelism. First, each PU can compute independently. Second, the CPU can compute independently of the VPU. Third, in the VPU, instruction fetch, decode, and execute can occur simultaneously. Fourth, within the FPU addition and multiplication can occur simultaneously. A user should only have to think about the first level. This determines the algorithm that is selected and how it is programmed. System software should be responsible for parallelizing on the lower levels. However, Hoshino and his colleagues have resorted to programming at all four levels in order to generate good performance from QCDPAX.

Programming

The host computer on QCDPAX runs a standard version of UNIX. A user's job is to write a main program for the host and programs for the PUs. Originally, PAX programs were written in Fortran, with some extensions. Now C is used for QCDPAX. This has been extended to allow programmers to communicate between nodes, to the host, etc. Complex arithmetic is supported. Assembly language is also available for taking advantage of the additional levels of parallelism mentioned above, and using it seems to be an essential part of getting optimal performance.

The structure of programs written to run on a PU will be almost entirely understandable to any experienced C programmer. There are some differences due to the communication. Thus variables can be declared as "fast," meaning that they are to be stored in the dm of the VPU; "slow," meaning that they are to be stored in lm of the PU; "north," "east," "south," or "west," meaning that they are to be stored in the communication memory and hence available to the adjacent processor; or "ferry," meaning that they are to be stored in the memory space that is mapped onto the hosts memory and hence are available to other PUs. The "vfor" loop forces computations *to occur in the* FPU; a more traditional "for" loop generates code that executes on the CPU.

```
vfor (k=0; k<NMAXAL; k+=1) {
 u[k] = a[k]*la[k];
 v[k] = 0.0;
 }
for (j=0; j<10; j+=1)
 l_ferry = l[j];
```

The "vfor" loop microcode instructions and data are sent to the VPU, where they begin executing. In this example both loops execute simultaneously. Usually, a "vfor" loop is inside a "for" loop. In that case the same microcode is sent to the VPU during each iteration of the "for," resulting in substantial overhead. Hoshino is working to have this transmission only occur once.

Hoshino always has felt that it was a mistake to try and develop very general parallel computers. At every opportunity he

emphasizes "simple is better." A good example is the two-dimensional lattice arrangement (NNM) of the PUs in PAX. In going from one to two to three dimensions the mean distance between PUs goes from P/2 to sqrt(P) to 1.5*cbrt(P) for P total processors. If P=4096 these values are 2048, 64, and 24. Thus, the incremental improvement in three dimensions is modest. Another well known parallel computer architecture is a "hypercube," in which 2**n PUs are arranged at the corners of an n-dimensional lattice. Rapid communication is possible with PUs sharing an edge. Communication with PUs that are further away takes longer because, on average, n/2 edges must be traversed. This is also an example of a nearest neighbor architecture. PAX is a two-dimensional specialization, but Hoshino believes that the more complicated hardware design of a hypercube reduces its efficiency. For example, the ratio of maximum communication overhead for a 4096-node hypercube (2**12) to a 4096-node PAX computer (2**6 by 2**6) is 128 to 12, about a factor of 10. But if overall communication overhead is 15 percent, reducing this, even to zero, does not contribute much to program speedup. It can also be easier to design, write, and debug programs for a "two-dimensional" computer compared to a higher dimensional one, but this depends upon the problem and the tools that are available for the user. On the other hand communication time has been a serious problem for many multiprocessing computers, and in those cases reducing communication costs by a factor of 10 would be extremely important. Further, some problems map better onto a higher dimensional arrangement. But Hoshino and other PAX researchers have shown in a number of papers that often the improvement is asymptotic and it may be difficult to achieve the best rate in practice.

Performance

Hoshino has repeatedly stated that any parallel processing research must be verified by actual implementation. Although some of his papers estimate the efficiency of PAX by mathematical analysis, he has run and measured performance on calculations including

- Poisson equation in two and three dimensions via successive overrelaxation (SOR), alternating direction implicit (ADI), and Fourier analysis cyclic reduction (FACR) methods
- Navier-Stokes equations via Beam-Warming, MacCormack, and SOLA methods
- Linear equations via Gauss-Jordan and conjugate gradient methods
- Molecular dynamics
- Plasma simulation via particle in cell (PIC) method
- Two-dimensional Heisenberg spin model
- Unsteady flow in flooding river
- Logic circuit analysis
- Quantum chromodynamics (QCD)

Peak measured performance is 8.25 GFLOPS on the 288-node QCDPAX. Expected peak performance will be 13.75 GFLOPS on the 488-node QCDPAX in March 1990. The table below, from Reference 6, indicates the measured performance of QCDPAX-240 on the solution of a three-dimensional Poisson

equation using a seven-point discretization stencil and red/black SOR iteration. The mesh is 360 x 370 x 360.

Update time per iteration, μs	199,294
Communication time, μs	265,214
Efficiency, %	42.9
GFLOPS	0.98
Time to converge, s	226.7

The figure of 42.9 percent efficiency given by Hoshino is computed as computation time divided by total time. The latter includes all the overhead associated with noncomputational tasks, primarily communication. The usual measure is the ratio of measured speedup relative to maximum theoretical speedup. Speedup is the ratio of time for serial processing to solve the problem to time for parallel processing.

QCDPAX

Computers with parallel processing capabilities that also require the user to formulate an algorithm in order to take advantage of parallelism are inherently special purpose. Some, such as the NASA Finite Element Machine (FEM) or Massively Parallel Processor (MPP), have been designed from the ground up for a particular class of problems; in the case of MPP this is satellite image processing. Others, such as the Cray YM/P-4, can be used for general computation without making use of parallel constructs. PAX, like a hypercube, is general purpose in the sense that the hardware and software are not restrictive. Both are special purpose in that some problems are much better suited to their architecture than others. They are also special purpose in that their power is from the large number of modestly powerful processors, rather than a modest number of very powerful ones. Within the context of this special purpose environment, the PAX researchers have always tried to develop a general purpose computer. The current QCDPAX is unusual because it alters this trend and was developed in response to funding pressures from the Ministry of Education, Science, and Culture.

QCDPAX joins together most of the original PAX researchers with physicists interested in a specific problem, quantum chromodynamics (QCD), and its discrete model, lattice gauge theory. QCD calculations involve massive amounts of random number generation, multiplication by 3 by 3 matrices, and computation of exponentials--all floating point operations. Thousands of hours of supercomputer time are required to generate interesting results. The computations are highly parallel and satisfy the proximity property, and thus are extremely well suited to PAX architecture. Special efforts have been made to speed up the software that is necessary for QCD. For example, 3 by 3 matrix multiplication has been written in microcode for the FPU, and complex floating point is supported in C. Several other research projects are attempting to develop special purpose computers for QCD calculations, notably at Columbia, CalTech, IBM, Rome, Edinburgh, and at FermiLab. A summary discussion of the progress of these groups through 1987 is given by Christ (Ref 1). In this report we have been considering PAX as a research project in parallel processing.

SUMMARY AND EVALUATION

Versions of PAX have been under development since 1977. They do not represent any new architectural breakthroughs. Instead PAX is a determined attempt to design a parallel computer that is simply built to work reliably, simply organized to

reduce the chore of programming, and not too special purpose. The application areas are those continuum problems satisfying the proximity property and for which substantial amounts of rapid floating point computation are required. QCDPAX is the most special purpose version of PAX, but only in the application programs and microcode that are specialized for QCD calculations, not in the hardware. The lessons learned building and running QCDPAX can be used directly in other versions, if these are built.

Although many computations have been performed on PAX computers over the years, in this author's opinion some of them do not use optimal algorithms. Further, the best PAX results are for two-dimensional problems, despite some extremely clever algorithmic implementations by Hoshino and others (see Ref 5). Nevertheless, their examples indicate the scope of potential applications. A number of specific types of computations seem very well suited to the PAX architecture, e.g., solving two-dimensional Laplace or Poisson equations using five-point discretization and periodic boundary conditions because the numerical solution at point P is determined by data at immediately adjacent points. Similarly, spin systems, because they are infinitely expandable homogeneous systems, are appropriate to the periodic boundaries of PAX computers. Further, these systems are controlled by the proximity property and, hence, most of the communication is between nearest neighbors.

The two-dimensional nearest neighbor approach of PAX has somewhat limited its applicability at the same time that it has made the design easier to build and to program. Its fast floating point unit is a great boost to performance, but it has caused many systems programming headaches. The PAX research group is very small. Writing microcode is time consuming and does not produce new physics. The C language extensions that enable users access to PAX's parallelism are easy to understand but their implementation still has bugs. Some of these have to be worked around via assembly language. Documentation at all levels is weak. What exists is entirely in Japanese. This is not as much of a disadvantage as it seems because program segments are the best models for writing new programs, and all programs are in English. However, without one-on-one assistance it would be difficult for a user outside of the PAX environment to utilize the machine. Funding for the current project is questionable after this year. At that time the Anritsu Corporation will take over the project and may repackage and market the computer. This will require a major commitment to refinement and maintenance of the software. I have no information if this will occur; Hoshino is not aware of Anritsu's intentions either. If PAX is commercialized, Anritsu will have to make use of the expertise in the PAX group, which could diffuse away if funding is not continued. Hoshino states that he is interested in adding a global addressing capability. He notes, correctly, that in many problems it is convenient to have a single, large data set available to all the PUs. The major supercomputers use this approach. Hoshino's research will continue in that direction. There seem to be good opportunities for scientists from the United States and elsewhere to visit and conduct joint research. As Hoshino has been developing parallel computers to solve real problems for many years, this would be very productive.

REFERENCES

1. N. Christ, "QCD machines," *Nuclear Physics B* (Proc. Suppl.) 9, 549-556 (1989).

2. R. Hockney and C. Jesshope, *Parallel Computers 2* (Adam Hilger, Bristol and Philadelphia, 1988).

3. T. Hoshino, "An invitation to the world of PAX," *Computer*, 69-79 (May 1986).

4. T. Hoshino, R. Hiromoto, S. Sekiguchi, and S. Majima, "Mapping schemes of the particle-in-cell method implemented on the PAX computer," *Parallel Computing* 9(1), 53-75 (December 1988).

5. T. Hoshino, Y. Sato, and Y. Asamoto, "Parallel Poisson solver FAGECR-- Implementation and performance evaluation on PAX computer," *J. Information Processing* 12(1), 20-26 (1988).

6. T. Hoshino, "Development of super parallel computer PAX and its applications," paper presented at the International Conference on Supercomputing in Nuclear Applications, SNA '90.

7. Y. Iwasaki, K. Kanaya, T. Yoshie, T. Hoshino, T. Shirakawa, Y. Oyanagi, S. Ichii, and T. Kawai, "Status of QCDPAX," paper presented at the Int. Symp. on Lattice Field Theory, LATTICE 89, September 1989, Capri, Italy.

8. Y. Iwasaki, T. Hoshino, T. Shirakawa, and Y. Oyanagi, "QCDPAX: A parallel computer for lattice QCD simulation," *Computer Physics Communications* 49, 449-455 (1988).

9. T. Shirakawa, T. Hoshino, Y. Oyanagi, Y. Iwasaki, T. Yoshie, K. Kanaya, S. Ichii, and T. Kawai, "QCDPAX - An MIMD array of vector processors for the numerical simulation of quantum chromodynamics," in *Proc. Supercomputing '89*, 13-17 November 1989, Reno, Nev., ACM Order Number 415892.

David K. Kahaner joined the staff of the Office of Naval Research Far East as a specialist in scientific computing in November 1989. He obtained his Ph.D. in applied mathematics from Stevens Institute of Technology in 1968. From 1978 until 1989 Dr. Kahaner was a group leader in the Center for Computing and Applied Mathematics at the National Institute of Standards and Technology, formerly the National Bureau of Standards. He was responsible for scientific software development on both large and small computers. From 1968 until 1979 he was in the Computing Division at Los Alamos National Laboratory. Dr. Kahaner is the author of two books and more than 50 research papers. He also edits a column on scientific applications of computers for the Society of Industrial and Applied Mathematics. His major research interests are in the development of algorithms and associated software. His programs for solution of differential equations, evaluation of integrals, random numbers, and others are used worldwide in many scientific computing laboratories.

THIRD NOBEYAMA WORKSHOP ON COMPUTATIONAL FLUID DYNAMICS, SUPERCOMPUTERS, AND TURBULENCE

Hideo Yoshihara

Background and description of the Nobeyama workshop are given together with a summary of some of the presentations. The workshop was composed of 30 invited papers on new developments in turbulence and computational fluid dynamics (CFD).

INTRODUCTION

The Third Biennial Nobeyama Workshop (as the first two) was held in the Yatsugatake Kogen Lodge, a resort hotel outside the small town of Nobeyama in the Japan Alps, a 2-hour bus ride northwest of Tokyo. The workshop was composed of 30 invited papers. The theme of the meeting was new concepts of turbulence and the interplay of computational fluid dynamics (CFD) and experiments. Co-chairmen of the workshop were Professor Kunio Kuwahara of the Institute for Space and Astronautical Sciences (ISAS) and Professor Steve Orszag of Princeton University. They are shown in Figure 1 in front of the meeting place, which normally hosts summer concerts. (The sign translates to Nobeyama Workshop Meeting Place.) There were 30 invitees from Europe and the United States and 49 from Japan, including many young researchers from research institutes, universities, and companies. The program would suggest the purpose of the workshop to be exposing Japanese attendees to the expertise of the invited foreign speakers. The workshop also served to establish personal relationships among the more experienced attendees that would promote future exchange of ideas.

Sponsorship of the workshop is unique in today's environment. It was formally hosted by the Keisan Ryutai Ryokugaku Kyokai (KRRK) (Computational Fluid Dynamics Society), a relatively informal organization composed of about 30 researchers from Japanese universities and research institutes. The president is Professor Kunio Kuwahara of ISAS and the vice president is Professor K. Nakahashi of Osaka Prefectural University. Membership in this organization is restricted. Annual dues are ¥50,000 (currently about $350). The theme of the workshop and the invitees were primarily chosen by Professor Kuwahara. The principal functions of the KRRK, aside from organizing the biennial workshop, are to provide travel support for young researchers to attend foreign meetings and to reprint

papers from foreign conferences. The major source of funds to support these activities as well as the workshop is from Fujitsu, Hitachi, and NEC, the three supercomputer manufacturers in Japan.

Figure 1. Co-chairmen, Professor K. Kuwahara (ISAS) and Professor S. Orszag (Princeton) in front of the workshop auditorium.

THE LECTURES

S. Orszag (Princeton U.), "Renormalization Group Theory of Turbulence." Professor Orszag and Dr. Yakhot extended an earlier renormalization group (RNG) turbulence theory by evolving turbulence models at several levels of the modeling hierarchy. Line-by-line it is a difficult theory to follow. Professor Orszag provided a more global, comprehensive explanation of the method and gave impressive examples. Comments after the talk criticized gaps in the theory, which were acknowledged by the speaker, but logic gaps are not uncommon in even the most respected turbulence theories. Two examples were for a transonic airfoil flow with a shock yielding excellent test/theory agreement and a large eddy simulation (LES) channel flow solution matching closely with direct simulation results with 1/60th of the computing time.

H. Sato (Inst. of Flow Research, Tokyo), "Does Turbulence Keep the Memory of Birth." Transition was induced in a two-dimensional wake by a low frequency coherent sound wave from a loud speaker. This low frequency coherent component persisted in the turbulence spectrum far downstream (100 initial wake heights). It was then suggested that after the initial trigger disturbance was damped, there was rebirth of the coherent component in the far downstream wake from seeds remaining from the initial sound disturbance. Others, however, would suggest that the initial disturbance had not yet died out and that turbulence sufficiently far downstream forgets details of its birth.

Fazle Hussain (U. of Houston), "Direct Simulation of Reconnection Mechanism." Reconnection is the reconfiguration of two aligned line vortices of opposite rotation into two U-shaped hairpin vortices. This observed phenomenon was reproduced by Professor Hussain by direct numerical simulation. Professor Nishioka (Osaka Prefectural U.), who was unable to attend the workshop, had earlier postulated a transition mechanism in terms of a hierarchy of hairpin vortices. He expressed satisfaction in a subsequent meeting that Professor Hussain was able to reproduce the hairpin vortices numerically.

K. Kuwahara (ISAS), "Simulation of Unsteady Flows and Their Visualization." There is little doubt that Professor Kuwahara's graphics capabilities rank among the very best so far as clarity of details and scope of data portrayed. Data displayed were generated by direct Navier/Stokes simulation. In the turbulent case, open questions remain regarding the role of numerical viscosity in the results.

J. Sethian (U. of Calif.-Berkeley), "Modeling of Viscous, Incompressible Flow in Arbitrary Geometries on a Massively Parallel Supercomputer." Planar incompressible viscous flow equations were programed on the 64K processor Connection Machine CM-2 using a random vortex method that is well suited for the massively parallel computer. Problems of large vortex structures, mixing, and shedding were calculated and graphically portrayed on a video tape. Relative merits of the CM-2 and, for example, the Cray YMP8/32 depend on the flow model and algorithm. Further experience with massively parallel computers is needed to gauge their relative performance.

N. Zabusky (Rutgers U.), "'DAVID' Environment and Application to Shock-Stratified Flows and Compressible Turbulence." DAVID (Data Visualization and Diagnostics) is a graphics software program that "quantifies, diagnoses, and validates" large numerical data sets. Its use is illustrated using the planar solution of the interaction of shock-generated vorticity on inclined density-stratified interfaces. The versatility of DAVID, permitting composite data displays including experimental data, was impressive. Users must await the three-dimensional version presently in development.

Two papers dealing with unstructured grid generation for complex configurations for use in finite volume calculations are T. Baker (Princeton U.), "Unstructured Mesh Generation and Its Application to Complete Aircraft Flowfield Computation," and K. Nakahashi (Osaka Prefectural U.), "An Automatic Flow Solver." (In addition to the grid generation part a Navier/Stokes flow solver was also described.) These two presentations are less fundamental fluid dynamically than the other papers previously described, but they are invaluable contributions for aerospace applications.

Two papers summarizing extensive aerospace calculations are V. Shankar (Rockwell Int.), "Supercomputing in Aerospace--Opportunities for Multidisciplinary Integration of Aerodynamics", and B. Wagner (Dornier Co.), "Some Recent Industrial Developments and Applications of CFD."

In all workshops of this series there have been progress reports on the latest supercomputers from the three sponsor companies. In this meeting presentations were given by Mr. T. Watanabe (NEC) and Mr. K. Uchida (Fujitsu), who are senior architects in the respective managements. Mr. Kawabe (Hitachi) was unable to be present. Mr. Uchida and Mr. Watanabe gave details of the new VP-2600 and SX-3 supercomputers, respectively. The VP-2600 (1 CPU, 4 GFLOPS peak CPU speed) will be available in the summer of 1990, while the SX-3 (4 CPU, 22 GFLOPS peak speed) will be available in September 1990.

Other papers in the order of presentation are:

- V. Yakhot (Princeton U.), "Probability Distributions in Turbulence"

- J. Hill (Iowa State U.), "DIA Theory and Full Turbulence Simulations of Heat Transfer in Decaying, Homogeneous Turbulence"

- R. Temam (U. of Paris), "The Nonlinear Galerkin Method in CFD"

- A. Patera [Mass. Inst. of Tech. (MIT)], "Parallel Spectral Element Simulation of Incompressible Flow"

- H. Keller (Cal Tech), "Wavy Taylor Vortex Flows Via Multigrid-Continuation Methods"

- L. Tuckerman (U. of Texas-Austin), "Numerical Simulation of Rayleigh-Benard Convection in a Cylindrical Geometry"

- E. Krause (RWTH-Aachen), "Comparison of Time-Dependent Flow Computations with Experiments"

- O. Inoue (Tohoku U.), "Effects of Multiple-Frequency Forcing on Turbulent Mixing Layers"

- M. Israeli (Technion-Israel), "Accurate Splitting Schemes for Time Dependent Flows"

- F. Baetke (Convex Corp.), "Optimizing the Performance of Flow Codes on Vector Computers"

- H. Yoshihara (Office of Naval Research Far East), "Navier-Stokes Algorithms and Supercomputers for Aerospace Applications"

- T. Aki (National Aeronautical Lab-Mitaka), "A Numerical Experiment on Implosions of Polygonally Interacting Shocks and Consecutive Explosion in a Square Box"

- R. Pletcher (Iowa State U.), "Observations on the Numerical Solution of the Compressible Navier-Stokes Equations at Low Mach Numbers"

- J. Ferziger (Stanford U.), "Composite Grid Methods" (a surprise presentation from a turbulence expert)

- C. Chu (Columbia U.), "Some Comments on the Computation of Global Ocean Circulations"

- R. Brown (MIT), "Large Scale Computation of Viscoelastic Flows"

- K. Ghia (U. of Cincinnati), "Low-Reynolds Number Nearly Chaotic Flows Past Airfoils at High Angle of Attack"

- U. Ghia (U. of Cincinnati), "Active Control of Two-Dimensional Separated Flow by Unsteady Forcing" (presented by K. Ghia)

Three cancelled presentations that would have added greatly to the workshop were:

- J. Kim (NASA-Ames), "Understanding the Basic Physics of Turbulent and Transitional Flows Using Direct Numerical Simulations"

- C. Liu and C. Hsu (NASA-Langley), "Numerical Studies of Vortex Flow Aerodynamics Using Incompressible Navier/Stokes Equations"

- S. Osher (U. of Calif.-Los Angeles), "Numerical Front and Shock Capturing"

SUMMARY COMMENTS

The subject matter and speakers at the third workshop were excellent. Many of the foreign participants attended all three workshops and commented on the continued improvements, both in terms of the physical arrangements and the presentations. Undoubtedly an important intangible result of the workshop has been the close friendships developed, as witnessed during the workshop, that have led to continuing international exchange of ideas.

INTERNATIONAL MEETINGS IN THE FAR EAST 1990-1995

Compiled by Yuko Ushino

The Japan Convention Bureau, the Science Council of Japan, and journals of professional societies are the primary sources for this list. Readers are asked to notify us of any upcoming international meetings and exhibitions in the Far East which have not yet been included in this report.

1990

Date	Title/Attendance*	Site	Contact for Information
May 16-18	Symposium on Neural-Networks; Alliance and Perspective in Senri (SYNAPSE)	Osaka, Japan	Senri International Information Inst. 15F, Hankyu-Grand Building 8-47 Kakuta-cho Kita-ku, Osaka 530
May 16-19	The 4th Multinational Instrumentation Conference (MICONEX '90) on Improving Productivity and Quality with Instrumentation and Control Systems	Beijing, People's Republic of China	Instrument Society of America P.O. Box 12277 67 Alexander Drive Research Triangle Park, NC 27709
May 17-19	1990 Yukawa International Seminar "Common Trends in Mathematics and Quantum Field Theories" (Seminar)	Kyoto, Japan	Secretariat 1990 Research Institute for Fundamental Physics (RIFP) Kyoto University Oiwake-cho, Kitashirakawa Sakyo-ku, Kyoto 606
May 20-25	The 9th International Symposium on Carotenoids	Kyoto, Japan	Professor Masayoshi Ito Kobe Women's College of Pharmacy 4-19-1 Motoyamakita-Machi Higashinada-ku, Kobe 658
May 20-25	The 17th International Symposium on Space Technology and Science	Tokyo, Japan	Ms. Hiroko Sakurai 17th ISTS Secretariat c/o Institute of Space and Astronautical Science 3-1-1 Yoshinodai Sagamihara, Kanagawa 229
May 21-22	Conference and Exhibition: Foundry Asia '90	Hong Kong	FMJ International Publications
May 21-23	4th Symposium on Our Environment	Singapore	Wong Ming Keong Dept. of Chemistry National University of Singapore Singapore 0511

*Note: Data format was taken from the Japan International Congress Calendar published by the Japan Convention Bureau.

No. of participating countries
F: No. of overseas participants
J: No. of Japanese participants

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
May 21-23	SEASI 34 Conference on Recent Developments and Applications of Hot/Cold Rolled and Coated Products	Taipei, Taiwan	Secretary General, SEASI P.O. Box 7759 Airmail Distribution Center NAIA, Pasay City 1300, Philippines
May 23-26	BIO JAPAN '90 OSAKA 20-F100-J300	Osaka, Japan	BIO JAPAN '90 OSAKA Secretariat c/o Inter Group Corp. Shohaku Building 6-23 Chayamachi Kita-ku, Osaka 530
May 28-June 1	The 8th International Conference on Modern Trends in Activation Analysis	Beijing, People's Republic of China	Chai Chifang Institute of High Energy Physics Academia Sinica P.O. Box 2732 Beijing
May 29-June 1	The International Conference on Manufacturing Systems and Environment - Looking Forward to the 21st Century	Tokyo, Japan	T. Nakajima Japan Society of Mechanical Engineers Sanshin Hokusei Building 2-4-9 Yoyogi Shibuya-ku, Tokyo 151
May 30-June 1	The 6th International Microelectronics Conference (IMC 1990) 20-F100-J600	Makuhari, Japan	Society for Hybrid Microelectronics 6-20-4 Hana Koganei Kodaira, Tokyo 187
June (tent.)	The 10th International Conference on Vacuum Metallurgy	Beijing, People's Republic of China	The Chinese Society of Metals 46 Dongsixi Dajie, Beijing 100711
June 4-5	International PU Forum 90 (Polyurethane)	Nagoya, Japan	PU International Forum Committee Sasajima Building c/o INOAC 1-23-17 Meieki-Minami Nakamura-ku, Nagoya 450
June 4-7	Joint International Conference on Marine Simulation and Ship Maneuverability (MARSIM & ICSM 90) N.A.-F130-J120	Tokyo, Japan	Secretariat: MARSIM & ICSM 90 c/o ISS International, Inc. 5F, Shinkawa Building 2-2-21 Shiba-koen Minato-ku, Tokyo 105
June 5-8	International Symposium on Reliability and Maintainability (ISRM 1990-Tokyo) 20-F200-J400	Tokyo, Japan	Union of Japanese Scientists and Engineers (JUSE) 5-10-11 Sendagaya Shibuya-ku, Tokyo 151
June 8-14	International Industrial Furnace Exhibition	Beijing, People's Republic of China	China International Exhibition Ctr, 6 East Beisanhuan Road Chaoyang District Beijing
June 11-12	The 1st United States-Japan Symposium on Advances in Welding Metallurgy	Undecided, Japan	American Welding Society P.O. Box 1082 Miami, FL 33256-1082

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
June 11-15	1990 International Conference: Metallurgical Coatings	Beijing, People's Republic of China	Chinese Society of Metals 46 Dongsixi Dajie, Beijing 100711
June 11-15	1990 International Conference: Special Melting	Beijing, People's Republic of China	Chinese Society of Metals 46 Dongsixi Dajie, Beijing 100711
June 15-20	The 2nd International Conference: Aluminum Alloys - Physical and Mechanical Properties	Beijing, People's Republic of China	Beijing University of Aeronautics and Astronautics Beijing 100083
June 18-22	C-MRS International '90	Beijing, People's Republic of China	Professor Hengde Li C-MRS International '90 Tsinghua University Beijing 100084
June 19-21	The 1990 Coal Handling and Utilization Conference	Sydney, Australia	The Conference Manager Coal Handling & Utilisation Conf. 1990 The Institution of Engineers, Australia 11 National Circuit Barton, ACT 2600
June 22-26	International Conference on Dynamics, Vibration, and Control	Beijing, People's Republic of China	Professor Wei Jinduo Chinese Society of Theoretical and Applied Mechanics No. 15 Zhong Guancun Street Beijing
June 24-27	The 5th Japan-U.S. Conference on Composite Materials	Tokyo, Japan	Professor Akira Kobayashi Department of Materials Science Faculty of Engineering University of Tokyo 7-3-1 Hongo Bunkyo-ku, Tokyo 113
June 24-27	Pacific Offshore Mechanics - 1990	Seoul, Korea	Secretariat: PACOMS '90, Korea Committee for Ocean Resources and Engineering (KCORE) c/o Dong-A University 840 Hadan-dong Saha-ku, Pusan 604-714, Korea
June 24-29	The 3rd International Symposium and Workshop, Society of Chinese Bioscientists of America	Hong Kong	Professor C.Y. Lee c/o Department of Biochemistry Chinese University of Hong Kong Shatin, Hong Kong
June 26-30	International Symposium on High Temperature Corrosion and Protection	Shenyang, People's Republic of China	Professor Man Yongfa Institute of Metal Research Academia Sinica 2-6 Wenhua Road Shenyang, Liaoning Province
June 27-29	International Symposium on Chemistry of Microporous Crystals (CMPC)	Tokyo, Japan	Professor Tomoyuki Inui Secretary, CMPC Department of Hydrocarbon Chemistry Faculty of Engineering Kyoto University Kyoto 606

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
June 28-July 3	IAGC/IMA Joint Symposium on Geochemistry, Mineralogy, and Origin of Ore Deposits in Relation to Future Materials	Beijing, People's Republic of China	IAGC c/o Alberta Research Council P.O. Box 8330 Postal Station F Edmonton T6H 5X2, Canada
July 1-5	The 1st Tokyo Conference on Advanced Catalytic Science and Technology (TOCAT 1) 20-F100-J200	Tokyo, Japan	Secretariat: TOCAT 1 c/o Department of Synthetic Chemistry Faculty of Engineering Tokyo University 7-3-1 Hongo Bunkyo-ku, Tokyo 113
July 1-6	The 3rd International Conference on Technology of Plasticity (3rd ICTP) 10-F300-J700	Kyoto, Japan	The Organizing Committee 3rd ICTP c/o The Japan Society for Technology of Plasticity Torikatsu Building 5-2-5 Roppongi Minato-ku, Tokyo 106
July 2-6	The 26th Yamada Conference "Surface as a New Material"	Toyonaka, Osaka, Japan	Professor A. Okiji Secretariat of YCS'90 Department of Applied Physics Osaka University 2-1 Yamadaoka, Suita 565
July 5-6	IEEE International Workshop on Intelligent Robots and Systems '90 (IROS'90)-Towards a New Frontier of Applications	Tsuchiura, Japan	Mr. Masakatsu Fujie IROS'90 Mechanical Engineering Research Lab Hitachi, Ltd. 502 Kandatsu-machi Tsuchiura-shi, Ibaraki-ken 300
July 6-7	The 1st KSME-JSME Fracture and Strength Conference (Fracture and Strength '90)	Seoul, Korea	Professor Hideaki Takahashi Research Institute for Strength and Fracture of Materials Tohoku University Aoba Tsurumaki Aza Sendai 980
July 9-11	Japan-U.S.A. Symposium on Flexible Automation - A Pacific Rim Conference	Kyoto, Japan	Professor Toshihiro Tsumura c/o Institute of Systems, Control at Engineers 14 Yoshida-Kawahara-cho Sakyo-ku, Kyoto 606
July 9-12	The 3rd International Conference on the Structure of Surfaces	Shanghai, People's Republic of China	Dr. M.A. Van Hove MCSD, Lawrence Berkeley Laboratory Berkeley, CA 94720
July 10-13	The 10th UOEH International Symposium and the 1st Pan-Pacific Conference on Occupational Ergonomics 12-F50-J150	Kitakyushu, Japan	Secretary General: Dr. M. Kumashiro Department of Ergonomics ILES, UOEH 1-1 Iseigaoka Yahatanishi-ku, Kitakyushu 807
July 11-13	The 5th International Conference on Manufacturing Engineering	Wollongong, Australia	The Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, ACT 2600

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
July 11-13	The 3rd Optoelectronics Conference (OEC '90) 8-F20-J350	Tokyo, Japan	Katsuyoshi Ito OEC '90 Publicity & Registration Subcommittee Chair c/o Business Center for Academic Soc. Japan Conference Department, Crocevia Crocevia Hongo 2F 3-23-1 Hongo Bunkyo-ku, Tokyo 113
July 12-14	Meeting on Advanced Research on Computers in Education	Tokyo, Japan	M. Hosaka Kikaishinko-kai 3-5-8 Shiba Koen Minato-ku, Tokyo 105
July 12-14	The 2nd International Symposium on Magnetic Bearings	Tokyo, Japan	Professor Toshiro Higuchi Institute of Industrial Science Tokyo University 7-22-1 Roppongi Minato-ku, Tokyo 106
July 12-17	IMA, the 15th Quadrennial General Meeting	Beijing, People's Republic of China	Professor Huang Yunhui Institute of Mineral Deposits Chinese Academy of Geological Sciences Baiwanzhuang Road 26 Fuchengmarwai, Beijing
July 15-21	The 10th International Congress of Nephrology 10-F1,000-J4,000	Tokyo, Japan	Japanese Society of Nephrology c/o 2nd Department of Internal Medicine School of Medicine, Nippon University 30-1 Oyaguchi-kamicho Itabashi-ku, Tokyo 173
July 16-19	1990 International Micro-Process Conference (MicroProcess '90)	Makuhari, Japan	Secretariat c/o Business Center for Academic Societies Japan Conference Department 3-23-1 Hongo Bunkyo-ku, Tokyo 113
July 16-20	Pacific Congress on Marine Science and Technology (PACON 90) 10-F100-J130	Tokyo, Japan	PACON 90 College of Science and Technology Nihon University 1-8-14 Surugadai, Kanda Chiyoda-ku, Tokyo 101
July 16-21	ISEC '90 International Solvent Extraction Conference 31-F150-J150	Kyoto, Japan	Conference Secretariat ISEC '90 Department of Chemistry Science University of Tokyo Kagurazaka, Shinjuku-ku, Tokyo 162
July 18-20	Advanced Research on Computers in Education	Tokyo, Japan	Professor Setsuko Otsuki Faculty of Computer Science and Systems Engineering Kyushu Institute of Technology 1-1 Sensui-cho, Tobata-ku Kitakyushu-shi, Fukuoka 804

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
July 18-21	The 3rd International Symposium on Human Factors in Organizational Design and Management 15-F100-J100	Kyoto, Japan	Dr. Junzo Watada Symposium Secretariat 3rd Internat'l Symp. on Human Factors in Organizational Design & Management c/o Faculty of Business Administration Ryukoku University Fukakusa, Fushimi, Kyoto 612
July 19-21	The 22nd International Congress of Applied Psychology (22nd ICAP) (Workshop)	Kyoto, Japan	Professor Yasuhisa Nagayama General Secretariat 22ICAP P.O. Box 38 Suita-Senri, Osaka 565
July 20-24	International Conference on Fuzzy Logic and Neural Networks (IIZUKA'90)	Fukuoka, Japan	Professor Takeshi Yamakawa Dept. of Computer Science and Control Engineering Kyushu Institute of Technology 680-4 Kawazu, Ohaza Iizuka-shi, Fukuoka 820
July 22-25	The 5th Asia-Pacific Confederation of Chemical Engineering (APCChE 1990)	Kuala Lumpur, Malaysia	Conference Sec'y APCChE Conference 1990 c/o The Institution of Engineers, Malaysia P.O. Box 223 (Jln Sultan) 46720 Petaling Jaya Malaysia
July 22-27	The 22nd International Congress of Applied Psychology (22 ICAP)	Kyoto, Japan	Professor Yasuhisa Nagayama General Secretariat, 22ICAP P.O. Box 38 Suita-Senri, Osaka 565
July 24-26	The 29th SICE Annual Conference (SICE'90)	Tokyo, Japan	Dr. Suguru Arimoto c/o Society of Instrument and Control Engineers (SICE) 1-35-28-303 Hongo Bunkyo-ku, Tokyo 113
July 29-August 3	IAWPRD BIENNIAL '90 (International Association on Water Pollution Research and Control)	Kyoto, Japan	Jun-ichiro Matsumoto, Chairman, Japanese Organizing Committee c/o Jpn Soc on Water Pollution Research Yotsuya New Mansion 307 12 Honshio-cho Shinjuku-ku, Tokyo 160
July 30-August 2	The 15th International Conference on International Association on Water Pollution Research and Control	Kyoto, Japan	Japan Soc. on Water Pollution Research and Control Yotsuya New Mansion 12 Honshiocho Shinjuku-ku, Tokyo 173
August 1-4	The 1st International Conference on Mechanics and Physics of Advanced Materials and Structures	Singapore	Professor G.C. Sih Institute of Fracture & Solid Mechanics Packard Laboratory Building No. 19 Lehigh University Bethlehem, PA 18015
August 2-8	The 25th International Conference on High Energy Physics 1990	Singapore	Professor K.K. Phua South East Asia Theoretical Physics Association c/o Dept. of Physics National University of Singapore Kent Ridge, Singapore 0511

1990			
Date	**Title/Attendance**	**Site**	**Contact for Information**
August 3-6	International Conf. on the Environmental Management of Enclosed Coastal Seas '90 (EMECS '90)	Kobe, Japan	Secretariat Exec. Comm. of the Internat'l Conf. on the Environmental Management of Enclosed Coastal Seas 5-10-1 Shimoyamate-dori Chuo-ku, Kobe 650
August 6-9	International Conference on Advanced Materials Mechanical Properties '90 (ICAMP'90)	Utsunomiya, Japan	Secretariat ICAMP'90 P.O. Box 1234, Shibuya Shibuya-ku, Tokyo 150
August 6-10	The 5th International Meeting of the International Humic Substances Society (IHSS5)	Nagoya, Japan	Registration Secretariat: 5th IHSS c/o Japan Convention Services, Inc. Nagoya Branch Nagoya International Bldg, 19th Floor 1-47-1 Nagono Nakamura-ku, Nagoya 450
August 7-9	International Symposium on Cereal and Other Plant Carbohydrates 15-F40-J250	Kagoshima, Japan	Organizing Committee of International Symposium on Cereal and Other Plant Carbohydrates c/o Dept of Agricultural Chemistry Faculty of Agriculture Kagoshima University 1-21-24 Korimoto Kagoshima 890
August 7-10	IUPAB Satellite Congress	Palmerston North, New Zealand	J. Tigyi Institute of Biophysics Medical University Szigeti ut 12 7643 Pecs, Hungary
August 7-11	International Symposium on Analytical Chemistry	Changchun, People's Republic of China	Professor Qinhan Jin Dept. of Chemistry Changchun, China
August 7-12	6th International Symposium on Biology of Turbellaria 24-F95-J70	Hirosaki, Japan	Professor Wataru Teshirogi Department of Biology Faculty of Science Hirosaki University 3 Bunkyo-cho Hirosaki, Aomori 036
August 12-17	The 15th International Carbohydrate Symposium 25-F200-J800	Yokohama, Japan	Dr. Ishido, General Secretary Faculty of Science Tokyo Institute of Technology Ookayama, Meguro-ku, Tokyo 152
August 12-18	The 14th International Congress of Soil Science 86-F1,200-J600	Kyoto, Japan	Secretariat of 14th ICSS 6-26-10-202 Hongo Bunkyo-ku, Tokyo 113
August 13-17	The 4th Asia Pacific Physics Conference	Seoul, Korea	Program Committee, AAPC Department of Physics Yonsei University Seoul 120-749, Republic of Korea

Date	Title/Attendance	Site	Contact for Information
		1990	
August 13-18	Tsukuba International Conference on Representations of Algebras and Related Topics 13-F50-J80	Tsukuba, Japan	Institute of Mathematics University of Tsukuba 1-1-1 Tennodai Tsukuba, Ibaraki 305
August 15-19	International Conference "Knot Theory and Related Topics" 20-F100-J150	Osaka, Japan	Professor A. Kawauchi Faculty of Science Osaka City University 3-3-138 Sugimoto Sumiyoshi-ku, Osaka 558
August 16-18	SIGNAL International Symposium on Algorithms	Tokyo, Japan	Professor Tetsuo Asano Department of Applied Electronics Osaka Electro-Communications University 18-8 Hatsu-cho Neyagawa-shi, Osaka 572
August 18-20	General Assembly, Internat'l Mathematical Union 52-F124-J6	Kobe, Japan	ICM 90 Secretariat c/o Research Institute for Mathematical Sciences Kyoto University Oiwake-cho, Kitashirakawa Sakyo-ku, Kyoto 606
August 20-21	The 7th VLSI Process/Device Modeling Workshop	Kawasaki, Japan	Mr. Hiroshi Iwai ULSI Research Center, Toshiba Corp. 1 Komukai-Toshiba-cho Saiwai-ku, Kawasaki 210
August 20-21	International Workshop on Frontiers in Plant and Microbial Glycans: Structure, Functions, and Biotechnology	Kyoto, Japan	Dr. Naoto Shibuya National Food Research Institute Ministry of Agriculture Forestry and Fisheries 2-1-2 Kannondai Tsukuba, Ibaraki 305
August 20-24	1990 International Symp. on Symbolic and Algebraic Computation 15-F60-J140	Tokyo, Japan	ISSAC '90 Conference Office c/o Scientist, Inc. Yamazaki Building 3-2 Kanda-Surugadai Chiyoda-ku, Tokyo 101
August 21-25	Western Pacific Geophysics Meeting (WEPGEM) 15-F200-J600	Kanazawa, Japan	Organizing Committee of WEPGEM c/o Professor I. Kimura Dept of Electrical Engineering Faculty of Engineering Kyoto University Yoshida-honmachi Sakyo-ku, Kyoto 606
August 21-29	International Congress of Mathematicians 1990 84-F1,500-J2,000	Kyoto, Japan	ICM 90 Secretariat c/o International Relations Office Research Inst. for Math. Sciences Kyoto University Kitashirakawa Oiwake-cho Sakyo-ku, Kyoto 606
August 22-23	International Workshop "Conformational Studies of Polysaccharides"	Osaka, Japan	Dr. Kozo Ogawa Osaka Prefectural Radiation Research Institute 174-16, Shinke-cho Sakai, Osaka 593

		1990	
Date	**Title/Attendance**	**Site**	**Contact for Information**
August 22-24	1990 International Conference on Solid State Devices and Materials N.A.-F100-J900	Sendai, Japan	c/o Business Center for Academic Societies Japan Crocevia Building 2F 3-23-1 Hongo Bunkyo-ku, Tokyo 113
August 23-30	V International Congress of Ecology 70-F1,300-J700	Yokohama, Japan	Sec'y General's Office for INTECOL 1990 c/o Inst. of Environmental Science and Technology Yokohama National University 156 Tokiwadai Hodogaya-ku, Yokohama 240
August 26-31	AUSTCERAM 90	Perth, Australia	Conference Secretariat, AUSTCERAM 90 P.O. Box 515 South Perth, WA 6151, Australia
August 27-31	The 2nd Japan-Soviet Union Joint Symposium on Computational Fluid Dynamics 4-F36-J100	Tsukuba, Japan	Dr. Y. Yoshizawa Institute of Engineering Mechanics University of Tsukuba 1-1-1 Tennodai Tsukuba 305
August 27-31	Step into the Nineties Joint Conference on Corrosion, Metals, Materials, Metal Finishing	Gold Coast, Australia	The Covener, Step into the 90's P.O. Box 198 Upper Mount Gravatt, QL, Australia 4122
August 28-31	International Conference & Exhibition on Computer Applications to Materials Science and Engineering (CAMSE 90)	Tokyo, Japan	Professor M. Doyama CAMSE '90 c/o The Nikkan Kogyo Shimbun, Ltd. Business Bureau 1-8-10 Kudan Kita Chiyoda-ku, Tokyo 102
August 29-September 4	The 11th International Symposium on Biotelemetry N.A.-F120-J250	Yokohama, Japan	Professor A. Uchiyama Dept. of Electronics & Communication School of Science and Engineering Waseda University 3-4-1 Okubo Shinjuku-ku, Tokyo 169
August 30-September 4	International Conference on Potential Theory 29-F100-J100	Nagoya, Japan	Secretariat International Conf. on Potential Theory c/o Department of Mathematics College of General Education Nagoya University Furo-cho, Chikusa-ku, Nagoya 464-01
August 30-September 4	International Symposium on Computational Mathematics 10-F30-J50	Matsuyama, Japan	Professor T. Yamamoto Department of Mathematics Ehime University 2-5 Bunkyo-machi, Matsuyama 790
August 31-September 4	International Symposium on Functional Analysis and Related Topics 13-F40-J60	Sapporo, Japan	Department of Mathematics Faculty of Science Hokkaido University Nishi 8-chome, Kita 10-jo Kita-ku, Sapporo 060

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Date	**Title/Attendance**	**Site**	**Contact for Information**
September 3-5	International Symposium on Diagnostics and Modeling of Combustion in Internal Combustion Engines (COMODIA 90)	Kyoto, Japan	Professor Makoto Ikegami Dept. of Mechanical Engineering Kyoto University Sakyo-ku, Kyoto 606
September 4-7	The 2nd International Symposium on Chemical Synthesis of Antibiotics and Related Microbial Products 23-F200-J500	Oiso, Japan	Faculty of Pharmaceutical Sciences University of Tokyo 7-3-1 Hongo Bunkyo-ku, Tokyo 113
September 10-14	The 17th Congress of the Collegium International Neuro-Psychopharmacologicum	Kyoto, Japan	The 17th CINP Congress c/o Simul International Inc. Kowa Building No. 1 1-8-10 Akasaka Minato-ku, Tokyo
September 12-14	The 12th International Symposium on Capillary Chromatography 30-F100-J250	Kobe, Japan	Assistant Professor Kiyokatsu Jinno School of Material Engineering Toyohashi University of Technology 1-1 Hibarigaoka, Aza Tenpaku-cho, Toyohashi-shi 440
September 16-20	The 4th International Conference on Copepoda	Karuizawa, Japan	Professor Shin-ichi Uye Hiroshima University, Shitami Shaijo-cho, Higashi-Hiroshima 724
September 16-22	The 15th IUMS Congress: Bacteriology & Mycology - Osaka, Japan - 1990 71-F2,000-J3,500	Osaka, Japan	Secretary General c/o Department of Microbiology Faculty of Medicine Kyoto University Yoshida, Konoe-cho Sakyo-ku, Kyoto 606
September 18-21	The 3rd Asia-Pacific Microwave Conference (APMC '90) 30-F150-J350	Tokyo, Japan	APMC '90 Secretariat c/o Business Ctr for Academic Societies Japan 3-23-1 Hongo Bunkyo-ku, Tokyo 113
September 19-22	The 2nd World Congress on Particle Technology N.A.-F100-J400	Kyoto, Japan	Secretariat: 2nd World Congress on Particle Technology c/o Society of Powder Technology, Japan Shibunkaku-kaikan 2-7 Tanakasekiden-cho Sakyo-ku, Kyoto 606
September 20-23	The 3rd Shallow Tethys International Symposium 15-F40-J60	Sendai, Japan	Secretariat of Shallow Tethys 3 c/o Inst. of Geology and Paleontology Faculty of Science Tohoku University Aobayama, Sendai 980
September 23-28	The 57th World Foundry Congress (WFC) 31-F400-J800	Osaka, Japan	Secretariat Japan Foundrymen's Society Toyokawa Building 8-12-13 Ginza Chuo-ku, Tokyo 104

		1990	
Date	**Title/Attendance**	**Site**	**Contact for Information**
September 24-27	The 6th International Congress on Polymers in Concrete	Shanghai, People's Republic of China	ICPIC-90 Secretariat c/o Associate Professor Tan Muhua Institute of Materials Science and Engineering Tongji University Shanghai
September 24-27	The 3rd International Aerosol Conference 29-F200-J300	Kyoto, Japan	Professor Kanji Takahashi c/o Institute of Atomic Energy Kyoto University Uji, Kyoto 611
September 24-28	The 12th International Conference: Boundary Element Method Conference (BEM 12) 15-F60-J160	Sapporo, Japan	Mr. Hiroshi Mizoguchi JASCHOME, KKE Inc. Dai-ichi Seimei Building 24F 2-7-1 Nishi-Shinjuku Shinjuku-ku, Tokyo 160
September 24-29	The 5th International Conference on Polymer Supported Reactions in Organic Chemistry (POC 90)	Kyoto, Japan	Dr. Takeo Shimidzu Division of Molecular Engineering Faculty of Engineering Kyoto University Yoshida-honmachi Sakyo-ku, Kyoto 606
September 24-29	IAGC, Geological Society of Australia, the 7th International Conference on Geochronology, Cosmochronology and Isotope Geochemistry	Canberra, Australia	IAGC c/o Alberta Research Council P.O. Box 8330 Postal Station F Edmonton T6H 5X2, Canada
September 28-October 2	4th International Symposium on Benthic Foraminifera: BENTHOS '90	Sendai, Japan	Organizing Comm. for 4th Int'l. Symp. on Benthic Foraminifera c/o Inst. of Geology and Paleontology Faculty of Science Tohoku University Aobayama, Sendai 980
October 1-5	International Conference on Information Technology Commemorating the 30th Anniversary of the Information Processing Society of Japan (IPSJ) - InfoJapan '90 20-F200-J1,000	Tokyo, Japan	InfoJapan '90 Secretariat: IPSJ Hoshina Building 3F 2-4-2 Azabudai Minato-ku, Tokyo 106
October 1-5	The 3rd International New Materials Conference (New Materials 90 Japan) 12-F100-J300	Osaka, Japan	Secretariat: New Materials 90 Japan c/o Inter Group Corp. Shohaku Building 6-23 Chayamachi Kita-ku, Osaka 530
October 2-5	4th International Conference on Shotpeening	Tokyo, Japan	Secretariat: ICSP Japan Society of Precision Engineering Ceramics Building 2-22-17 Hyakunin-cho Shinjuku-ku, Tokyo 169

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Date	**Title/Attendance**	**Site**	**Contact for Information**
October 8-9	The 1st International Symposium on Functionally Gradient Materials	Sendai, Japan	The Society of Non-Traditional Technology Toranomon Kotohira Kaikan Building 3F 1-2-8 Toranomon Minato-ku, Tokyo 105
October 8-10	The 1st International Workshop on Algorithmic Learning Theory (ALT'90)	Tokyo, Japan	Professor Setsuo Arikawa Program Chairman of ALT'90 Research Inst. of Fundamental Information Science Kyushu University 33 Fukuoka 812
October 8-11	"Benibana" International Symposium on How to Improve the Toughness of Polymers and Composites 10-F40-J110	Yamagata, Japan	Professor Ikuo Narisawa Polymer Materials Engineering Yamagata University 4-3-16 Jonan Yonezawa-shi, Yamagata 992
October 8-12	The 5th Australasian Remote Sensing Conference	Perth, Australia	Gold West Conventions P.O. Box 411 West Perth, WA 6005
October 8-12	The 6th International Symposium on Biomineralization 17-F55-J45	Odawara, Japan	Professor S. Suga Department of Pathology School of Dentistry The Nippon Dental University 1-9-20 Fujimi Chiyoda-ku, Tokyo 102
October 9-12	Fracture and Fatigue of High-Performance and Multi-Phase Polymeric Materials 8-F25-J60	Undecided, Japan	Faculty of Engineering Yamagata University 4-3-16 Jonan Yonezawa, Yamagata 992
October 11-12	The 2nd KSME-MSME Fluids Engineering Conference	Seoul, Korea	Professor Jinho Lee Dept of Mechanical Engineering College of Engineering Yonsei University 134 Shinchon-dong, Seodaemun-ku Seoul 120-749
October 12-14	The 3rd Japan-China Joint Meeting on Optical Fiber Science and Electromagnetic Theory	Fukuoka, Japan	Professor Takashi Hidaka Dept of Electronic Engineering College of Science & Technology 1-8-14 Kanda Surugadai Chiyoda-ku, Tokyo 101
October 14-19	International Conference for New Smelting Reduction and Near Net Shape Casting Technologies for Steel	Pohang, Korea	Conference Department Institute of Metals 1 Carlton House Terrace London, SW1Y 5 5DB, U.K.
October 15-18	The 1st Asian-Pacific International Symposium on Combustion and Energy Utilization	Beijing, People's Republic of China	Prof. Huang, Zhao Xiang and Song Jialin Institute of Engineering Thermophysics Chinese Academy of Sciences P.O. Box 2706, Beijing

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Date	Title/Attendance*	Site	Contact for Information
October 15-19	The 4th International Symposium on Marine Engineering (ISME KOBE '90) 25-F120-J330	Kobe, Japan	ISME Organizing Committee c/o Kobe Shosen Daigaku 5-1-1 Fukae-Minami Higashinada-ku, Kobe 658
October 15-19	The 8th International Symposium on Vit. B6 and Carbonyl Catalysis 20-F80-J80	Osaka, Japan	Institute of Scientific and Industrial Research 8-1 Mihogaoka Ibaraki, Osaka 567
October 15-19	The 11th Meeting of International Collaboration on Advanced Neutron Sources (ICANS - XI) 10-F40-J60	Tsukuba, Japan	National Laboratory for High Energy Physics 1-1 Oho Tsukuba, Ibaraki 305
October 15-27	International Electrotechnical Commission, the 54th Annual General Meeting	Beijing, People's Republic of China	Chinese National Committee of the IEC P.O. Box 820 Beijing
October 21-26	The 6th International Iron and Steel Congress 50-F300-J500	Nagoya, Japan	International Conference Department Iron and Steel Institute of Japan 3F, Keidanren Kaikan 1-9-4 Otemachi Chiyoda-ku, Tokyo 100
October 22-25	The 11th International Coal Preparation Congress N.A.-F250-J150	Tokyo, Japan	Secretariat 11th Int'l Coal Preparation Congress c/o Simul International, Inc. Kowa Building, No. 9 1-8-10 Akasaka Minato-ku, Tokyo 107
October 22-25	10th International Acoustic Emission Symposium 1990 (IAES-10)	Sendai, Japan	Professor Hiroaki Niitsuma Faculty of Engineering Tohoku University Aramaki Aza Aoba, Sendai 980
October 22-26	International Conference on Signal Processing	Beijing, People's Republic of China	Professor Zong Sha Nongzhan Guan Nan Lu 12, Room 2307 Beijing 100026
October 22-26	International Conference on Information Technology in Connection with 30th Anniversary Celebration of Information Processing Society of Japan N.A.-F200-J1,000	Osaka, Japan	Secretariat: International Conference on Information Technology c/o Simul International, Inc. Kowa Building, No. 9 1-8-10 Akasaka Minato-ku, Tokyo 107
October 25-31	The 1st Japanese Knowledge for Knowledge-Based Systems Workshop (JKAW)	Kyoto, Japan	Assoc. Professor Riichiro Mizoguchi Institute of Scientific and Industrial Research 8-1 Mihogaoka Ibaraki, Osaka 567

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October 28-November 2	The 2nd International Conference: HSLA Steels	Beijing, People's Republic of China	Chinese Society of Metals 46 Dongsixi Dajie, Beijing 100711
October 29-31	The 5th International Workshop on Atmospheric Icing of Structures 20-F100-J150	Tokyo, Japan	Secretariat for 5th International Workshop on Atmospheric Icing of Structures c/o Inter Group Corp. Akasaka Yamakatsu Building 8-5-32 Akasaka Minato-ku, Tokyo 107
October 29-November 1	Japan International Tribology Conference Nagoya - '90 N.A.-F200-J600	Osaka, Japan	Secretariat: Japan ITC Nagoya - '90 c/o Toyota Technological Institute 2-chome, Hisakata Tempaku-ku, Nagoya 468
October 29-November 2	International Symposium on Mineral Exploration - Use of Artificial Intelligence, 1990 (ISME - AI '90) N.A.-F30-J70	Tokyo, Japan	Mining and Materials Processing Institute of Japan (MMIJ) Nogizaka Building 9-6-41 Akasaka Minato-ku, Tokyo 107
October 29-November 4	The 14th International Pigment Cell Conference 12-F200-J200	Kobe, Japan	Organizing Committee XIVth International Pigment Cell Conference c/o Department of Dermatology Kobe University School of Medicine 7-5-2 Kusunoki-cho Chuo-ku, Kobe 650
November 4-8	International Symposium on Carbon, 1990: "New Processing and New Applications" 15-F50-J200	Tsukuba, Japan	The Carbon Society of Japan Saito Building 2F 2-16-13 Yujima Bunkyo-ku, Tokyo 113
November 5-8	The 9th International Symposium on Zirconium in the Nuclear Industry 20-F100-J100	Kobe, Japan	American Society for Testing and Materials (ASTM) Conference Department 1916 Race Street Philadelphia, PA 19103
November 7-9	IUPAC International Symposium on Specialty Polymers	Singapore	Professor S.H. Goh Department of Chemistry National University of Singapore 10 Kent Ridge Crescent Singapore 0511
November 11-13	Metal Bulletins 6th International Aluminum Conference	Singapore	Metal Bulletin Conferences Ltd. House Park Terrace, Worcester Park Surrey KT4 7HY, U.K.

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Date	**Title/Attendance**	**Site**	**Contact for Information**
November 26-29	The 3rd SPSJ International Polymer Conference (IPC 90) - Membranes and Interfacial Phenomena of Polymers 5-F100-J200	Nagoya, Japan	IPC Secretariat c/o Society of Polymer Science, Japan 5-12-8 Ginza Chuo-ku, Tokyo 104
November 26-30	The 5th International Photovoltaic Science and Engineering Conference (International PVSEC-5)	Kyoto, Japan	Professor Junji Saraie Secretariat of International PVSEC-5 c/o Japan Convention Services, Inc. Nippon Press Center Building 2-2-1 Uchisaiwai-cho Chiyoda-ku, Tokyo 100
November 28-30	IAPR Workshop on Machine Vision Applications	Tokyo, Japan	Professor Mikio Takagi Institute of Industrial Science University of Tokyo 7-22-1 Roppongi Minato-ku, Tokyo 106
November (tent.)	The 3rd International Symposium on Superconductivity 17-F100-J700	Undecided, Japan	International Superconductivity Technology Center 6F Eishin Kaihatsu Building 5-34-3 Shinbashi Minato-ku, Tokyo 105
December 4-7	ICCV3 Third International Conference on Computer Vision	Osaka, Japan	Professor Saburo Tsuji Dept of Control Engineering Faculty of Engineering Science 1-1 Machikaneyama-cho Toyonaka, Osaka 560
December 6-8	The 6th International Conference on Biomedical Engineering	Singapore	Dept of Orthopedic Surgery National University Hospital Lower Kent Ridge Road Singapore 0511
1990 (tent.)	Chemeca 1990 Applied Thermodynamics	New Zealand	Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, ACT 2600

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Date	**Title/Attendance**	**Site**	**Contact for Information**
February 7-12	The 10th International Conference on Offshore Mechanics and Arctic Engineering	Seoul, Korea	Korea Cmt for Ocean Resources & Engrng Dong-A University 840 Sahagu Pusan, Korea
February 10-15	Polymer 91 IUPAC International Symposium - Polymer Materials Preparation, Characterization, and Properties	Melbourne, Australia	Polymer 91 Secretariat R.A.C.I. Polymer Division P.O. Box 224 Belmont, VIC 3216, Australia
March 11-15 (tent.)	Computing in High Energy Physics '91 19-F100-J100	Tsukuba, Japan	National Laboratory for High Energy Physics 1-1 Oho Tsukuba, Ibaraki 305

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Date	**Title/Attendance***	**Site**	**Contact for Information**
November 13-16	Annual Meeting of International Lead Zinc Research Organization 10-F40-J20	Tokyo, Japan	Process Technology Department Mitsubishi Metal Corp. P.O. Box 227 Sonic City Building 1-441 Sakuragi-cho, Omiya 331
November 14-15	TECHNO-OCEAN '90 International Symposium 7-F50-J350	Kobe, Japan	Kobe International Association 6-9-1 Minatojima-Nakamachi Chuo-ku, Kobe 650
November 14-15	Kyushu International Techno-Business Forum 7-F150-J450	Kitakyushu, Japan	Secretariat Kyushu International Techno-Business Forum c/o Enterprise Development Division, Economic Affairs Bureau Kitakyushu City Office 1-1 Jonai Kokura Kita-ku, Kitakyushu 803
November 14-16	Pacific Rim International Conference on Artificial Intelligence '90	Nagoya, Japan	Secretariat: PRICAI '90 Inter Group, Inc. Akasaka Yamakatsu Building 8-5-32 Akasaka Minato-ku, Tokyo 107
November 14-16	Rare Metals '90 15-F100-J200	Kitakyushu, Japan	Mining and Materials Processing Inst. of Japan (MMIJ) Nogizaka Building 9-6-41 Akasaka Minato-ku, Tokyo 107
November 18-20	I-SAIRAS '90 - International Symposium on Artificial Intelligence, Robotics, and Automation for Space 7-F50-J200	Kobe, Japan	Ren Planning & Research Office 2nd Kikke Building 2-12-14 Hamamatsu-cho Minato-ku, Tokyo 105
November 18-22	1990 International Conference on Spoken Language Processing (ICSLP-90)	Kobe, Japan	Secretariat: ICSLP-90 c/o Simul International, Inc. Kowa Building No. 9 1-8-10 Akasaka Minato-ku, Tokyo 107
November 19-22	Asia Pacific Interfinish 90 Congress	Hong Kong	Asia Pacific Interfinish 90 c/o Australasian Inst. of Metal Finishing 191 Royal Parade Parkville, VIC 3052, Australia
November 19-23	Corrosion-Air, Sea, Soil: CASS 90	Auckland, New Zealand	Professor G. Trabanelli Corrosion Study Center Department of Chemistry University of Ferrara Via L. Borsari 46 I-4410 Ferrara, Italy

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Date	**Title/Attendance**	**Site**	**Contact for Information**
March 12-15	The 4th International Conference on Ceramic Powder Processing Science 20-F250-J350	Nagoya, Japan	Secretariat 4th Int'l Conf. on Ceramic Powder Processing Science c/o Dept of Applied Science Faculty of Engineering Nagoya University Furo-cho, Chikusa-ku, Nagoya 464
March 18-19	VISICOM '91 (Packet Video 91)	Kyoto, Japan	Mr. Hideo Hashimoto Visual Media Laboratories Human Interface Laboratories 1-2356 Take Yokosuka-shi, Kanagawa 238-03
March 18-20	IEEE International Conference on Microelectronic Test Structures	Kyoto, Japan	Dr. Yukinori Kuroki Micro Electronics Research Labs NEC Corp. 1120 Shimokuzawa Sagamihara-shi, Kanagawa 229
March 21-23	VISICOM '91 (PCS 91)	Tokyo, Japan	Mr. Hideo Hashimoto Visual Media Laboratories Human Interface Laboratories 1-2356 Take Yokosuka-shi, Kanagawa 238-03
April 4-12	The 7th International Conference on Data Engineering	Kobe, Japan	Professor Tadao Ichikawa Dept of Circuit & Electrical System Engineering Faculty of Engineering Shitami, Saijo-cho Higashi Hiroshima-shi, Hiroshima 724
April 8-12	IFIP TC5/WG 5.10 Working Conference on Modeling in Computer Graphics	Tokyo, Japan	Toshiyasu L. Kunii, Program Chairperson IFIP TC5/WG 5.10 Working Conference Dept of Information Science University of Tokyo 7-3-1 Hongo Bunkyo-ku, Tokyo 113
April 11-13	IMAC '91 - International Conference on Image Management and Communication in Patient Care	Kyoto, Japan	Dr. Eiichi Takenaka Department of Radiology National Defense Medical College 3-2 Namiki, Tokorozawa 359
May 7-13	Beijing Essen Welding '91	Beijing, People's Republic of China	Messe Essen Nobert Street D-4300 Essen Federal Republic of Germany
May 13-17	The 5th International Symposium on Toxicity Assessment 25-F100-J30	Kurashiki, Japan	Toxicity Assessment: Kurashiki Symposium Committee c/o Dr. I. Aoyama Research Institute for Bioresources Okayama University 2-20-1 Chuo, Kurashiki 710
June 3-6	International Conference on Superplasticity in Advanced Materials (ICSAM-91)	Osaka, Japan	Assistant Professor N. Furushiro Dept of Materials Science and Engineering Osaka University 2-1 Yamadaoka Suita-shi, Osaka 565

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June 10-12	The 3rd International Conference on Hot Isostatic Pressing	Osaka, Japan	Professor Yoshinari Miyamoto Processing Research Center for High Performance Materials Institute of Scientific and Industrial Research Osaka University 8-1 Mihogaoka Ibaraki-shi, Osaka 567
June 10-13	International Conference on Stainless Steels 20-F50-J100	Tokyo, Japan	Secretariat: STAINLESS STEELS '91 The Iron and Steel Institute of Japan Keidanren Kaikan 1-9-4 Otemachi Chiyoda-ku, Tokyo 100
June 10-14	The 4th International Conference on Nucleus-Nucleus Collisions 20-F200-J200	Kanazawa, Japan	The Inst. of Physical and Chemical Research (RIKEN) 2-1 Hirosawa Wako, Saitama 351-01
June 12-15	The 18th International Materials Handling, Storage and Distribution Exhibition and Conference	Tokyo, Japan	Show Management, Yoshihisa Shiraishi Convention Department, Japan Management Association 3-1-122 Shiba Koen Minato-ku, Tokyo 105
June 17-21	10th International Symposium on the Mathematical Theory of Networks and Systems (MTNS-91) 30-F180-J170	Kobe, Japan	Professor Hidenori Kimura Dept. of Mechanical Engineering for Computer-Controlled Machinery Faculty of Engineering Osaka University 2-1 Yamadaoka Suita-shi, Osaka 565
June 23-29	The 6th Marcel Grossmann Meeting on General Relativity 31-F380-J170	Kyoto, Japan	Secretariat 6th Marcel Grossmann Meeting on General Relativity c/o Professor F. Sato Department of Physics Faculty of Science Kyoto University Kitashirakawa Oiwake-cho Sakyo-ku, Kyoto 606
June 30-July 4	The 6th Southeast Asian/Western Pacific Regional Meeting of Pharmacologists	Hong Kong	Professor C.W. Ogle Hong Kong Pharmacology Society Department of Pharmacology Faculty of Medicine University of Hong Kong Pokfulam Road, Hong Kong
June (tent.)	JIMIS-6: Intermetallic Compound - Properties and Applications	Tokyo, Japan	Professor Osamu Waizumi Institute for Materials Research 2-1-1 Katahira Sendai 980
July 1-5	International Conference on Hot Carriers in Semiconductors 10-F70-J80	Nara, Japan	Department of Electronics Osaka University 2-1 Yamadaoka Suita, Osaka 565

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Date	**Title/Attendance**	**Site**	**Contact for Information**
July 7-12	World Congress on Medical Physics and Biomedical Engineering (9th ICMP - 16th IFMBE) 54-F1,000-J1,500	Kyoto, Japan	Secretariat World Congress on Medical Physics and Biomedical Engineering c/o Japan Convention Services, Inc. Kansai Branch Sumitomo Seimei Midosuji Building 4-14-3 Nishitemma Kita-ku, Osaka 530
July 8-13	The 6th International Conference on Chemistry of Selenium and Tellurium 12-F30-J120	Osaka, Japan	Professor N. Sonoda, Chairman of Organizing Committee of 6th Int'l. Conf. on Chemistry of Selenium and Tellurium Dept of Applied Chemistry Faculty of Engineering Osaka University 2-1 Yamadaoka Suita, Osaka 565
July 15-17	The 7th International Conference on Vapor Growth and Epitaxy 15-F60-J350	Nagoya, Japan	ICVGE-7 Committee c/o Professor I. Akasaki Department of Electronics Faculty of Engineering Nagoya University Furo-cho, Chikusa-ku, Nagoya 464-01
July 24-26	The 3rd International Conference on Residual Stresses (ICRS-3) 30-F150-J200	Tokushima, Japan	Society of Materials Sciences, Japan 1-101 Yoshida Izumidono-cho Sakyo-ku, Kyoto 606
July 24-30	The 17th International Conference on the Physics of Electronic and Atomic Collisions	Brisbane, Australia	Dr. W.R. Newell Department of Physics University College of London Gower Street London WC1E 6BT UK
July 29-August 2	The 6th International Conference on Mechanical Behavior of Materials (ICM-6) 30-F300-J300	Kyoto, Japan	Society of Materials Sciences, Japan 1-101 Yoshida Izumidono-cho Sakyo-ku, Kyoto 606
August 18-23	The 11th International Conference on Structural Mechanics in Reactor Technology 45-F300-J700	Tokyo, Japan	SMirt-11 c/o Komae Research Laboratory Central Research Institute of Electric Power Industry 2-11-1 Iwato-kita Komae, Tokyo 201
August 25-31	IUPAC International Congress on Analytical Science-1991 (ICAS '91) 25-F500-J1,000	Chiba, Japan	Japan Society for Analytical Chemistry Rm 304 Gotanda Sun Heights 1-26-2 Nishi Gotanda Shinagawa-ku, Tokyo 141
August 28-30	1991 International Conference on Solid State Devices and Materials	Yokohama, Japan	c/o Business Center for Academic Societies Japan Crocevia Building 2F 3-23-1 Hongo Bunkyo-ku, Tokyo 113

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Date	**Title/Attendance**	**Site**	**Contact for Information**
September 5-10	The 12th IMEKO World Congress (IMEKO XII)	Beijing, People's Republic of China	Instrument Society of America P.O. Box 12277 67 Alexander Drive Research Triangle Park, NC 27709
September 8-13	The 5th International Conference on II-VI Compounds	Okayama, Japan	Professor Makoto Konagai Electrical and Electronic Engineering Faculty of Engineering 2-12-1 Ookayama Meguro-ku, Tokyo 152
September 12-14	IMEKO TC7 8th International Symposium on Artificial Intelligence Based Measurement and Control (AlMaC '91) 25-F50-J100	Kyoto, Japan	Professor Komyo Kariya Dept of Electrical Engineering Faculty of Science and Engineering Titsumeikan University 56-1 Tojin-Kita Kita-ku, Kyoto 603
September 24-28	The 9th International Symposium on Affinity Chromatography and Biological Recognition (9th AC & BR) 23-F150-J200	Yokohama, Japan	9th AC & BR Organizing Committee c/o Professor K. Kasai Faculty of Pharmaceutical Sciences Teikyo University Sagamiko Tsukui, Kanagawa 199-01
September 25-28	International Congress on Flexible Manufacturing in Sheet Metal Working	Hong Kong	Uta Bates Mack-Brooks Exhibitions, Ltd. Forum Place, Hatfield AL10 ORN, U.K.
September 26-29	The 3rd International Conference on Steel-Concrete Composite Structures 7-F30-J270	Fukuoka, Japan	Department of Architecture Faculty of Engineering Kyushu University 6-10-1 Hakozaki Higashi-ku, Fukuoka 812
September 27-30	The 2nd Osaka International Colloquim on Ship Viscous Flow (OC '91)	Osaka, Japan	Professor T. Okuno Department of Naval Architecture College of Engineering University of Osaka Prefecture Nozu-Umemachi, Sakai, Osaka 591
September 29-October 4	The 5th Asian Pacific Congress of Clinical Biochemistry (5th APCCB) 20-F300-J600	Kobe, Japan	Secretariat: 5th APCCB c/o Central Laboratory for Clinical Investigation Osaka University Hospital 1-1-50 Fukushima Fukushima-ku, Osaka 553
September 30-October 3	IFAC/ISHS Workshop on Mathematical and Control Applications in Agriculture and Horticulture	Matsuyama, Japan	Assistant Professor Hiroshi Nonami Dept of Biomechanical Systems Ehime University 3-5-7 Tarumi Matsuyama-shi, Ehime 790
October 2-4	International Conference on Ion Exchange '91	Tokyo, Japan	Secretariat c/o Japan Assoc. of Ion Exchange (JAIE) Department of Chemistry Faculty of Science 2-12-1 Ookayama Meguro-ku, Tokyo 152

1991			
Date	**Title/Attendance**	**Site**	**Contact for Information**
October 14-16	International Conference on Recent Advances in Science and Engineering of Light Metals (RASELM '91) in Commemoration of 40th Anniversary of the Japan Institute of Light Metals	Sendai, Japan	Secretariat: RASELM '91 c/o Professor K. Ikeda Dept of Materials Processing Faculty of Engineering Tohoku University Aoba, Sendai 980
October 15-19	1991 International Symposium on Lattice Field Theory 20-F140-J30	Tsukuba, Japan	National Laboratory for High Energy Physics 1-1 Oho Tsukuba, Ibaraki 305
October 21-23	Small Engine Technology Conference (SETC)	Yokohama, Japan	Gobancho Center Building 5F Society of Automotive Engineers of Japan, Inc. 10-2 Goban-cho Chiyoda-ku, Tokyo 102
October 27-November 2	The 6th International Pacific Conference on Automotive Engineering	Seoul, Korea	IPC-6 Conference Secretariat Korea Society of Automotive Engineers, Inc. 1638-3 Socho-dong, Socho-ku Seoul 137
October 28-31	International Conference on Fast Reactors and Fuels Cycles 8-F150-J350	Kyoto, Japan	Power Reactor & Nuclear Fuel Development Corp. 1-9-13 Akasaka Minato-ku, Tokyo 107
October 28-November 1	International Conference on Industrial Electronics, Control, and Instrumentation (IECON '91) 30-F200-J400	Kobe, Japan	Society of Instrument and Control Engineers of Japan (SICE) #303, 1-35-28 Hongo Bunkyo-ku, Tokyo 113
November 5-8	The 13th International Telecommunications Energy Conference (INTELEC '91)	Kyoto, Japan	Mr. Katsuichi Yotsumoto Applied Electronics Laboratories 3-9-11 Midori-cho Musashino-shi, Tokyo 180
November 18-22	International Conference on Accelerator and Large Experimental Physics Control Systems 15-F90-J80	Tsukuba, Japan	National Laboratory for High Energy Physics 1-1 Oho Tsukuba, Ibaraki 305
November (tent.)	The 1st Japan-China Joint Seminar of Filtration and Separation	Shanghai or Hangchou, People's Republic of China	The Society of Chemical Engineers, Japan 4-6-19 Kohinata Bunkyo-ku, Tokyo 112

1992			
Date	**Title/Attendance**	**Site**	**Contact for Information**
February (tent.)	The 19th Australian Polymer Symposium	Perth, Australia	RACI Polymers Division P.O. Box 224 Belmont, VIC 3216
May 17-22	NETWORKS '92: The 5th International Network Planning Symposium 30-F200-J150	Kobe, Japan	NTT Telecommunication Networks Labs 3-9-11 Midori-cho Musashino-shi, Tokyo 180
August 3-8	The 8th International Congress of Biorheology 20-F300-J200	Yokohama, Japan	8th ICBR (Int'l Cong. Biorheology) Local Organizing Committee c/o Department of Physics Keio University 832 Hiyoshi-cho Kohoku-ku, Yokohama 223
August 24-September 3	The 29th International Geological Congress 30-F1,000-J2,000	Kyoto, Japan	IGC Secretariat P.O. Box 65 Tsukuba, Ibaraki 305
August 30-September 4	The 9th International Congress on Photosynthesis 20-F500-J500	Nagoya, Japan	Professor Norio Murata Okazaki National Research Institute National Research for Basic Biology 38 Saigou-Naka, Miyoudaigi-cho-aza Okazaki, Aichi
September 22-25	1992 International Symposium on Antennas and Propagation (ISAP-92)	Sapporo, Japan	Dr. Ken-ichi Kagoshima R&D Laboratories NTT 1-2356 Take Yokosuka-shi, Kanagawa 238-03
October 26-30	The 14th International Switching Symposium (ISS '92) 60-F1,200-J800	Yokohama, Japan	NTT Communication Switching Labs 3-9-11 Midori-cho Musashino-shi, Tokyo 180
November 9-12	The 8th International Congress on Heat Treatment of Materials (HEAT & SURFACE '92) N.A.-F-J500	Kyoto, Japan (tentative)	Secretariat of 8th Int'l Congress on Heat Treatment of Materials c/o Research Inst. for Applied Science 49 Tanaka Ohi-cho Sakyo-ku, Kyoto 606

1993			
Date	**Title/Attendance**	**Site**	**Contact for Information**
February 16-20	International Federation of Clinical Chemistry, the 15th Triennial World Congress	Melbourne, Australia	Dr. David Hay Royal Womens Hospital 132 Gratten Street Carlton, VIC 3053, Australia
May 23-28	The 18th International Mineral Processing Congress	Sydney, Australia	AUSIMM, Conference Department P.O. Box 122 Parkville, VIC 3052

1993			
Date	**Title/Attendance**	**Site**	**Contact for Information**
July 12-15	1993 International Powder Metallurgy Conference & Exhibition 40-F200-J400	Kyoto, Japan	Japan Powder Metallurgy Association Tamagawa Building 2-2-16 Iwamoto-cho Chiyoda-ku, Tokyo 101
August 8-13	The 8th International Congress of Virology	Osaka, Japan	Prof. Stuart W. Glover, Sec'y General Int'l Union of Microbiological Soc. Dept of Genetics, Catherine Cookson Bldg Framlington Place Nerocastle upon Tyne NE2 4HU, UK
Late August	The 25th Congress of IAHR (International Assoc. of Hydraulic Research) 40-F400-J600	Tokyo, Japan	Local Organizing Committee of 25th IAHR Cong. c/o Professor Y. Iwasa School of Civil Engineering Kyoto University Yoshida-honmachi Sakyo-ku, Kyoto 606
1993 (tent.)	International Federation of Automatic Control Congress	Sydney, Australia	Conference Manager The Institution of Engineers, Australia 11 National Circuit Barton, ACT 2600

1994			
Date	**Title/Attendance**	**Site**	**Contact for Information**
Tentative	XXX International Conference on Coordination Chemistry	Kyoto, Japan	Professor Hitoshi Ohtaki Coordination Chemistry Laboratories Institute for Molecular Science Myodaiji-cho, Okazaki 444
Tentative	The 10th International Conference on the Strength of Metals and Alloys (ICSMA-10)	Undecided, Japan	Professor Hiroshi Oikawa Faculty of Engineering Tohoku University Aoba, Aramaki Aza Sendai 980

1995			
Date	**Title/Attendance**	**Site**	**Contact for Information**
Tentative	The 13th International Vacuum Congress (IVC-13) 7th International Conference on Solid Surfaces (ICSS-7)	Undecided, Japan	Vacuum Society of Japan 302 Kikai Shinko Kaikan Annex 3-5-22 Shiba-koen Minato-ku, Tokyo 105
Undecided	World Energy Council '95 90-F-J5,000	Undecided, Japan	Japan Energy Association Uchisaiwai Building 1-4-2 Uchisaiwai-cho Chiyoda-ku, Tokyo 100

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